The Twentieth Century

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THE TWENTIETH CENTURY
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EDITORIAL NOTE

Each autumn the British public turns to the British Association meetings for news and views of science; this year, with the recent Geneva meetings on atomic power still in mind, the intelligent layman's interest in the implications of scientific advance is perhaps sharper than usual. THE TWENTIETH CENTURY decided to invite a few leading scientists to contribute to a scientific number addressed not to the specialist but to the average, educated non-scientist who is anxious to comprehend some of the problems presented.

The number opens with a layman's plea for independence in the pursuit of pure knowledge (and closes with a not dissimilar plea on behalf of another kind of creative worker, the artist). Appropriately the scientific contributions begin with an account of the physicists' disinterested search for the ultimate structure of matter: high-energy physics – to which the atom and its nucleus are now almost *vieux jeux* – has already nearly exhausted the Greek alphabet in naming newly discovered fundamental particles. Next, and nearer to earth, two articles discuss the implications of the power which physics is putting behind the elbow of industrialized society: will 'automation' and the displacement of animate by inanimate energy-slaves prove subtler threats to social stability than atom-warfare to international peace? Both biological contributions deal with aspects of immunology. the defence mechanism by which the body recognizes and rejects what is foreign to itself. Aberrations of this process can, however, be fatal; this and other ineptitudes in man's evolution may question whether Mind or matter ordained some of our bodily ills. Since science started as 'natural philosophy' it should be natural for scientists to be philosophers: metaphysics followed physics in the orderly mind of Aristotle. The formulation and communication to each other of our thoughts, and of our culture to other societies, are the subject of the last two scientific articles. Our customary book notes are curtailed so that the phantasies of science-fiction may be reviewed.

Science: a Layman's View

G. F. Hudson

SCIENCE was not always with us; it is a comparatively late comer to the human scene. In long ages of history distinguished in other respects by high civilization, it has been absent or has appeared only in a rudimentary form. Having arrived, however, it has proceeded to change both our conception of natural phenomena, and our capacity for dealing with them, out of all recognition. The transformation of the material conditions of human life through the advances of technology over the last two centuries has gone on at a tempo of progress unprecedented in the millennia of man's previous experience. Man himself, however, who has brought all this about, has himself changed least of all, so that there is to-day a remarkable dichotomy in our civilization between one sphere of human life which the historian sees as utterly different from the past and another in which he feels quite at home. Our world of electronics, supersonic aircraft, television and hydrogen bombs is something quite outside the experience of mankind, not only in ancient and medieval times, but even when Queen Victoria died. On the other hand, politicians and officials in our time seem to behave in much the same way as they did in Nineveh and Tyre, the Tell-el-Amarna Tablets disclose an international diplomacy very similar to that of the twentieth century, and the essential relations of human beings as portrayed by Homer are those with which we are familiar in our own everyday life.

The electric water-heater, we are told by the advertisers, is one of the Four Foundations of Modern Living, the other three being the electric cooker, the electric space-heater and the electric washing machine. All can be had (at a price) from your Electricity Service Centre. On these foundations, it appears, is raised the superstructure of our civilization. But how did the Electricity Service Centre come to be able to provide such wonderful things? It is because of researches and experiments carried out by scientists since the middle of the

eighteenth century by which man has attained understanding of electrical phenomena. It was not, of course, a discovery of electricity; primitive man had already been only too uncomfortably aware of the occurrence of lightning, which played a major part in the world-picture of his mythical imagination. The ancient Greeks knew that the gods had no intention of teaching mortal men how to wield this awful and mysterious power; they had even grudged man the use of fire, and Zeus had punished Prometheus with an exemplary penalty for daring to steal it. The Olympians were not disposed to bestow on mortals the gift of an electric washing machine; man had to find out for himself how to make one. The gods, however, have at least become more tolerant of such human impiety, and the technicians of later times have been spared the fate of Prometheus. Man has been left to his own devices, and as a result of these devices it is clear that he is now going somewhere at a high speed of progress, though just where he is going is by no means so manifest.

The inventors of electric washing machines, atomic explosions and other Foundations of Modern Living are the heirs of Prometheus, but with an important difference. Prometheus wanted to benefit mankind by providing it with something useful, but it is not recorded that he was interested in the theory of light and heat; it was enough that it was known from experience that fire would cook a meal, warm a room, provide illumination in darkness or burn down an enemy city in war. The idea of a theoretical science divorced from practical aims and disinterestedly devoted to the pursuit of truth by rigorous, systematic abstract thinking came later in Greek history. It was exemplified in the Greek story of the man who wanted to study under Euclid and asked him how he could turn geometry to practical use; Euclid is said to have ordered his slave to give the enquirer some money 'since he needs to make a profit from what he learns'. A socially minded modern critic would no doubt point out that as a man of private means Euclid could afford to take such a disinterested view of his quest for truth and that his attitude of aristocratic contempt for the uses of knowledge was part of a social order based on slavery and a low esteem for industrial crafts. But the cultivation of science as a pursuit of knowledge for its own sake did not have the effect of turning it into the hobby of a leisured class without any bearing on the economic life of mankind; on the contrary, it turned out

to be the indispensable condition for the great advances of science which ultimately produced the victorious technology of the modern age. Historically it is not a fact that the major developments of science have been due to a specially strong determination to increase man's command over nature or to improve the processes of material production. Craftsmen in all ages have sought to improve their techniques, but in the absence of systematic theoretical scientific thinking their advances – often remarkable enough – were limited to what could be achieved by trial-and-error methods, accumulated experience and lucky accidents. The Greeks were not pre-eminent in technology; it was in 'useless' abstract thinking, and, above all, in geometry, that they excelled, and the pioneers of modern science, although laying greater stress than the Greeks on experimental verification, carried on a tradition which was concerned with exploring and understanding the universe rather than with productive techniques. Without this activity of disinterested enquiry the great practical discoveries and applications of theory which have so transformed the conditions of human life in more recent times would not have been possible. Even the most sensational and revolutionary of all the wonder-working innovations of modern science, the emergence of atomic physics, goes back to investigations of the structure of matter which originally seemed to be of purely philosophical importance.

Science to-day has two aspects which, though closely interrelated, remain fundamentally distinct – the pure science whose aim is simply to know about the universe, and the scientific technology which seeks to harness natural forces to human ends through the application of such knowledge. The distinction has important implications both for the approach to scientific problems and for the relation of the scientist to society. In pure science the sole concern of the enquirer is with truth and error, and, however truth is philosophically defined, it is certainly understood as imposing a test which is independent of human desires, interests or prejudices. In technology, on the other hand, the ultimate criterion is one of practical success in relation to the needs and wishes of the employer or customer. In pure science the direction of enquiry is determined simply by the existence of fields of phenomena not yet explored and unsolved problems which have arisen in those fields; in technology the problems are set by the economic, political and

strategic demands and it makes a great deal of difference what groups in society and the state can best make their wishes into effective demands. It follows that the technologist as such, even though he may be a trained scientist and work with scientific concepts, does not need to worry too much about truth if he can get immediate practical results which satisfy those who seek his services. The significance of this will be clear if we consider contemporary doctrines which identify science and technology and treat all scientific thinking as merely instrumental in the attainment of social and economic ends. The Marxist-Leninist conception of a division between 'bourgeois science' and 'socialist science' corresponds to this view of the nature of science as a human activity; if scientists are not persons who are genuinely seeking truth as far as they are able to ascertain it, but merely experts who are doing odd jobs for the rulers of the state or the owners of the means of production, then it is quite reasonable to argue that they must get different orders and directives according to the social system under which they are working. The narrowly practical man of affairs, whether industrialist or politician, sets very little value on the intellectual integrity and detachment of the pure scientist; he respects science because it has apparently turned out to be essential to the exploits of the higher technology, but if the technician were to produce his effects by the use of Aladdin's lamp, he would be just as well pleased.

If we turn from the natural to the social sciences, there is a similar situation, though in a different, and much closer, relation to social interests and purposes. There are the pure sciences of anthropology, sociology, psychology and economics which simply seek to study and explain human behaviour as a part of the phenomena of the universe, and there is a corresponding technology of experts who use the information and theoretical constructions of these sciences in aid of public administration, fiscal policy, welfare work or public relations. It is extremely difficult for these social technicians not to become deeply *engagés* in moral and political causes, with deleterious effects on their objectivity in study of the facts, and the case is worse still if they become part of a bureaucracy which is committed to certain policies and opinions. The hope that the social sciences may help man to improve the ordering of his own affairs in a way comparable to the assistance of the natural sciences in his mastery over the forces of nature runs into the

fact that political and economic groups tend to have a strong vested interest in beliefs convenient to themselves and tend to regard social scientists not as independent investigators but as counsel for advocacy of positions already taken up.

In the contemporary world there are various kinds of pressure on scientists to conform to standards other than those of free critical scientific enquiry and discussion. These pressures vary from the thorough-going attempts of totalitarian states to impose an orthodox philosophical doctrine over the whole field of thought down to mild, but nevertheless pernicious, efforts of public authorities in democratic countries to give a cloak of scientific justification to decisions taken on political and administrative grounds. In the Soviet Union, in spite of high honours paid to scientists and provision on a very large scale for scientific education, science has been drastically fettered up to now by a system of thought-control designed to enforce conformity with the Marxist-Leninist doctrine, which is a complete philosophy of the cosmos as well as a political creed. Originally advanced as a hypothesis in sociological controversy, and with a fair claim to be a scientific theory at the time of its formulation, Marxism ceased to be scientific when its tenets were raised to the status of a revealed dogma and given the backing of a ruthless police power. Under this régime there has been nothing left for the social sciences to do but to amplify and illustrate conclusions which are laid down in advance by the pontiffs of the new secular religion. The natural sciences have fared better, but that is mainly because of the régime's demand for military and industrial technology; work in theoretical physics has been restricted by the requirements of dialectical materialism, and in biology the controversy with Lysenko led to a number of his opponents being not merely dismissed from their posts but sent to forced labour camps. The point of the Lysenko affair was not the question whether his views were correct or not – though no non-Communist geneticist of repute ever seems to have regarded him as other than a charlatan – but the fact that the political bosses of the Communist party took it on themselves to decide a matter of scientific controversy and to use the power of the state to crush those who refused to conform to the decision.

In this country there is no persecution of unorthodox scientific views, and discussion of scientific theories is entirely free. There have nevertheless been some disquieting symptoms

of a tendency on the part of public authorities to manipulate scientific opinion in support of policies which have been decided on non-scientific grounds. A recent example of this was the government decision to prohibit the manufacture of heroin. This decision was taken as a radical measure for putting an end to heroin addiction and the illicit traffic in the drug. But heroin was also used extensively in medical practice, and unless an adequate substitute was available, the ban on manufacture involved increased suffering for a large number of hospital patients. It is apparently the general view of practising doctors that there is as yet no effective substitute for heroin in most of the cases in which it is used. There was therefore in this matter a difficult social problem of weighing the interest of society in the enforcement of the criminal law against the interest of society in the successful treatment of disease. But the government, instead of holding a thorough enquiry in which all competent points of view on the question could be heard, chose to issue a public declaration that there could be no objection to a ban on heroin because adequate substitutes existed. It has been claimed that the government consulted its official medical advisers before making this statement. Yet it could not but strike the ordinary layman as strange that the opinion of the government's medical advisers should agree with the wishes of the police authorities rather than with the prevailing view of independent members of their own profession. Nor is this an isolated case. Scientists holding official advisory posts often seem to develop an outlook which is not strictly scientific. It is not that they are mercenary or subject to any form of compulsion; it is simply that, being involved in the processes of government, they develop habits of mind typical of the politician or civil servant. Instead of the rigorous disinterested standards of scientific investigation and criticism, they come to inhabit the world of inter-departmental conflicts and compromises, of political tactics and administrative convenience, of log-rolling and face-saving, of official bromides, platitudes and blah.

It is indeed essential not only that there should be complete freedom of opinion in science but also that there should always be a sufficient number of scientists outside industry and government administration to maintain a body of completely independent opinion on all questions of scientific truth. In an age of superlative achievement in technology and ever-increasing

demand for the services of scientists both by private economic enterprise and by public authorities, it is more than ever necessary to defend the integrity of pure science as a disinterested quest for truth. This is required ultimately even in the interest of that utility in which those who disparage purely intellectual values suppose the significance of science to lie. Since the evidence of history is that the greatest advances in technology have been made not through concentration on practical ends but from the effort to explore and understand the universe, it is reasonable to assume that in the future also a society which fetters pure science in the interest of religious or political dogma, or seeks to organize it as a mere auxiliary in the performance of practical tasks, will in the long run get a technology inferior to that of a society which values and esteems the pursuit of truth for its own sake. The freedom of science is thus not simply a right or claim of scientists themselves but an interest of the layman as well, of the vast non-scientist majority of society who are the beneficiaries of science through technology.

In another and much deeper sense also the layman, if he is a free citizen of a democratic society, has an interest in the maintenance of the freedom and integrity of the scientific mind. The layman who does not aspire to the systematic exploratory thinking of the professional scientist nevertheless tries to think for himself independently to some extent; the basis of all liberal theory is that the ordinary man should be treated as a rational being and not as a mere subject of the state, whose beliefs as well as his actions must be ordered from above by an infallible authority. The professional scientist is thus as it were the specialized representative of the ordinary man as a free rational human being and citizen. If there is no freedom for the scientist, there is *a fortiori*, no freedom for anyone; if the scientist turns aside from his dedication to the pursuit of truth, the whole of humanity must sink back into primitive – even though perhaps pseudo-scientific – dogmatism and superstition. There is indeed an essential connection between the freedom of pure science and the values of civil and political liberty, and a totalitarian ideology must logically involve an attack on pure science. That this is so the history of the Nazi and Communist movements has abundantly demonstrated. Modern totalitarian parties want scientists for economic and military technology and are prepared to reward them highly as long as they are

obedient servants, but what these new secular religions cannot tolerate is the idea of individuals seeking the truth for themselves and declaring their conclusions without permission from their political bosses.

The cause of intellectual freedom would, however, be a much simpler issue if it were not confused by a considerable number of desertions from the ranks of the scientists themselves. Although it might be supposed that every scientist would appreciate the importance of preserving conditions of maximum freedom for his work, there have in recent years been not a few voluntary recruits from the ranks of science to totalitarian movements. This *trahison des clercs* presents an interesting psychological problem. One powerful motive has undoubtedly been the growth of a sense of guilt among scientists at the calamitous consequences of certain scientific inventions, particularly in their application to the making of weapons of mass destruction. In the Victorian Age the scientist was normally honoured as the benefactor of mankind and any misuse of his gifts was not considered to be his responsibility. But more recently, and especially since the invention of the atomic bomb, there has been a widespread popular feeling that the uncontrolled progress of science has turned out to be a curse to humanity, and the scientist himself, affected by these emotions, has felt that he must assume responsibility for the use of his discoveries and, as it were, follow them up and take charge of their applications. To this new sense of social responsibility, arising from dismay at some of the consequences of scientific progress, have been added in some cases impulses of a different kind – a new will to power and disposition to claim that the scientist, having worked such wonders in the control of the forces of nature, should now be given the job of setting right the affairs of the human race. These two convergent motives driving the scientist out from the study and the laboratory into the arena of politics have been exploited by totalitarian propagandists who have flattered some scientists into the belief that under a system of absolute state power the men of science and not ignorant political bosses would really make policy.

But the scientist has no special responsibility over and above that of any other citizen for the use or misuse of scientific knowledge. Nor do his special qualifications as a scientist give him any exceptional competence for the adjustment of human

relations or the solution of moral and political issues; indeed, as far as the natural sciences are concerned, his characteristic habits of mind may be a definite disqualification, for a mind accustomed to think of nature as material to be moulded or manipulated by an operator can only too easily carry over such a conception of purely external control into the entirely different problems of man's ordering of his own life. The scientist in politics is indeed just as much of a monstrosity as the politician in science. The responsibility for the uses and applications of scientific discovery rests on society as a whole and the agencies to which its powers may be delegated. The sole responsibility of the scientist as such is to pursue truth and to make it known to the best of his ability. But there is nothing in the world more important.

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The Frontier of Physics

R. E. Peierls

TO most laymen physics to-day means atoms, or their nuclei, and atomic nuclei mean atomic bombs or power stations. But to the physicist these discoveries are only by-products of the continuing search for the secrets of nature. This is not to say that they are discoveries upon which the scientist stumbled by accident, because the process of gaining an understanding of the laws of nature is intimately connected with developing the power to control the forces of nature.

Modern science relies upon the experimental approach. New ideas are based on observations of natural processes and are accepted only when they lead to predictions of new phenomena which are tested by experiment. We believe in the truth of our description only if they enable us to use the forces of nature for some new purpose.

This need not be a useful purpose. The proof that a physical theory has come closer to the truth than its predecessors is often obtained from the delicate movement of a galvanometer needle or the shape of a track in a photographic plate, but the power to make nature perform exercises, as it were, is closely associated with achieving more practical results.

It is therefore not surprising that again and again important steps in the search for an understanding of nature have immediately been recognized as capable of practical application. Thus Faraday's discovery of the law of induction led directly to the electric generator, the work of Clerk Maxwell and Hertz on the nature of electromagnetism to radio waves. Innumerable other examples could be added to this list.

In the search for truth it is not possible to see many moves ahead. It is not possible to predict what new applications will follow from any particular study, and it should be stressed that there are many important new advances in our understanding which are of no immediate practical use. I am not suggesting that the scientist can be indifferent to the results of his work,

which may profoundly alter the shape of the world of which he is part. But his search for knowledge has to be carried on without knowing what will come of it.

To-day the front line of physics has moved far beyond the problems of the atomic nucleus, though many problems concerning the nucleus are not yet solved and are related to the questions now being studied. What use this new work may be ultimately to the ordinary citizen is impossible to say, unless the citizen derives some satisfaction from watching the progress in our understanding of nature. At the present there is no reasonable prospect of any useful applications, but in the light of history it would be rash to deny that such a possibility might exist.

The new problems of physics derive directly from the study of the structure of matter. Until the end of the last century the structure of matter was essentially the domain of the chemist. Chemistry had listed the chemical elements, about ninety-two in number, of which all other substances are built up according to definite laws. The physicist was concerned with describing the behaviour of matter in various situations. The physicist knew, of course, that glass is transparent and coal is black, that copper is a good conductor of electricity and rubber an insulator, that lead is ductile and steel hard, but these were facts to be looked up in a catalogue, and the reasons were not his concern.

By this time chemistry had led to the atomic hypothesis, according to which all matter consists of atoms, each atom characteristic of a chemical element. Chemical compounds consist of molecules in which atoms are combined in fixed proportions, one molecule of water, for example, containing one atom of oxygen to two atoms of hydrogen. This idea had been suggested by the quantitative rules which had been found to govern the formation of chemical compounds, and it had been one of the first results of the tendency of modern science to apply quantitative measurement rather than qualitative observation to the study of nature. The idea that matter might consist of small indivisible units was of course very old, but it was not a fruitful idea as long as there was no way of testing whether it was right or wrong, or of obtaining any information on the nature of these small units. In its application to chemical compounds the idea could be put to a quantitative test, and one was able to determine the weights of different atoms in

relation to each other. Thus the weight of an atom of oxygen was found to be sixteen times that of the hydrogen atom. Yet one did not know the absolute size of either, and the final confirmation of the idea was obtained only when it became possible to determine the weight and size of an atom. Towards the end of the nineteenth century several methods for deducing the size of an atom were developed, and when they all gave the same answer the 'atomic hypothesis' had advanced from a working hypothesis to an undoubted fact.

About the same time physicists began to take an interest in the motion and general behaviour of atoms. They had studied and had learnt how to describe electricity and magnetism, and in studying the passage of electric currents through gases they discovered a small particle carrying a negative electric charge, and nearly 2,000 times lighter than the lightest atom. This, the so-called electron, was evidently an important constituent of matter.

Its function in the structure of the atom was cleared up by the work of Rutherford, who showed that the atom was like a small planetary system. Like planets around the sun, in the atom a number of electrons revolve round the nucleus, a heavy positively charged object which carries practically the whole weight of the atom. The similarity extends even to the fact that the atom is as empty as the planetary system, i.e. the diameter of the nucleus in relation to the whole is about as small as the diameter of the sun in relation to its distance from the planets.

Since unlike electric charges attract each other, the atom normally tends to be neutral, i.e. to have as many negative electrons attached to it as will equal the positive charge of the nucleus. And indeed the atoms of different chemical elements differ simply by having nuclei of a different electric charge and therefore carrying different numbers of electrons.

Since the nature of the electric force between the nucleus and the electrons was well understood, it seemed a simple task to study the motion of the electrons in their orbits in the same manner in which astronomers can forecast, with high precision, the motion of the planets around the sun. However, all attempts to do this failed at first. Amongst the many facts that it seemed impossible to account for was the remarkable stability of atoms; no matter how violently one disturbed the motion of the electrons, they would in time settle down into orbits of

exactly the same kind as before, so that each atom when undisturbed had a perfectly definite size and behaved in a perfectly definite way. This is quite different from the planetary system. The only reason why the earth and other planets stay in their definite orbits is the absence of disturbances. If our sun with its planets experienced a close encounter with another star, we would find as a result a completely different configuration of planetary orbits.

The key to this mystery was found in the very revolutionary ideas first proposed by Planck, according to which the ordinary laws of mechanics and of electricity are not correct on the very small scale of atomic phenomena. Planck's ideas were first developed to account for the radiation emitted by a hot body, and meant there that light, which we had learnt to regard as consisting of electromagnetic waves, also behaved as if it consisted of a definite number of particles, or 'photons', each of which carried a definite amount of energy if it belonged to light of a definite colour. These ideas were applied by Niels Bohr to the mechanics of the atom, and were there seen to give rise to an equally revolutionary change in our ideas of the fundamental laws of mechanics.

The ideas of Planck and Bohr immediately helped to explain many facts about atoms. Their success left no doubt that they were moves in the right direction, but it took some time before they were developed into a completely detailed and consistent set of laws and thus could be applied to all problems involving atoms. The completion of these ideas were mainly due to the work of de Broglie, Heisenberg and Schrödinger, who showed that, just as Planck had found light waves to behave sometimes like assemblies of particles, similarly electrons and other particles behave sometimes as if they were waves. This duality, and the reason why these statements are not contradictory, form the content of quantum mechanics, which cannot be satisfactorily described in this brief article.

The application of quantum mechanics to the atom led immediately to a complete understanding of all phenomena involving atoms, and hence of the structure of matter. Admittedly many of the problems involving a large atom with many electrons, or perhaps even very many such atoms, are too complex, and require too much mathematics, for a complete and detailed solution. But one is confident that it is only the mathematical difficulties which prevent a complete description, be-

cause in all those cases where the problems are simple enough for either an exact, or at least a good approximate, solution of the equations, the results are in complete agreement with experiment.

At this stage, then, all the phenomena of physics could be boiled down to the basic laws of quantum mechanics and of electricity. For a complete description of an atom one had to specify only the weight of the atomic nucleus and the amount of positive charge it carried. This latter number varies from the smallest charge, that of the hydrogen nucleus, which is opposite and equal to the negative charge of the electron, to ninety-two times this amount for uranium, the heaviest element known in nature. In this sense our knowledge of the atom was complete. The atom certainly was very far from the indivisible, immutable unit imagined by the Greek philosophers, but its centre was the nucleus, which for all the purposes so far discussed could be regarded as immutable. But long before this time it was known that the nuclei of some elements, such as radium, tended to break up spontaneously and to throw out charged particles. Rutherford had succeeded in breaking up other nuclei as well by bombarding them with the very fast particles obtained from the disintegration of radium. This kind of work became easier when Cockcroft and Walton designed a machine to accelerate charged particles, in particular atomic nuclei, artificially to velocities similar to those of the radium particles, and used these particles for disintegrating atomic nuclei. For this one has to use particles of high velocity, in order that they should overcome the electric repulsion of other nuclei, and that on impact they should cause a sufficiently violent disturbance to break up the nucleus which they hit.

Great progress has been made in accelerating particles to higher and higher energies. Such energies are measured in million electron volts (MeV). One MeV is the energy which a particle of one electronic charge acquires in moving through an electric potential difference of one million volts. Whereas the first experiments by Cockcroft and Walton were done with a fraction of an MeV, the latest particle accelerator (in Berkeley, California) gives about 6,000 MeV, and machines for energies of the order of 20,000 MeV are under construction.

At the same time the development of the work would not have been possible without new and ingenious methods of detecting the results of such disintegrations, i.e. detecting

single nuclei moving at speed. Devices such as the particle counter, which signals the passage of a single fast nucleus, or the cloud chamber, which makes the track of such a particle visible (like the vapour trail of a high-flying aircraft), or the photographic plate, which records similar tracks as rows of black dots, are now commonplace.

As a result of this work it was found that nuclei, like atoms, were not indivisible, but were built of two simple units: the proton, or hydrogen nucleus, a heavy particle of a positive charge equal and opposite to that of the electron, and the neutron, a particle of the same weight, but electrically neutral.

These particles evidently are held together in the nucleus with very strong forces, since a bombardment with very fast particles is necessary to tear them apart. The problem arose immediately of understanding the nature of these forces. They differed from electric forces in having a very short range. Whereas the attraction between two opposite electric charges follows the inverse square law, just like the gravitational attraction which keeps the earth in its orbit around the sun, the nuclear forces act only when particles are as close to each other as they are normally within the nucleus, and have no effect at greater distances. No wonder therefore that, until we were able to study the interior of the nucleus, we had no previous experience of this kind of force.

The short range of the forces led the Japanese physicist Yukawa to speculate about the way in which such forces would be propagated through space, and his reasoning led to the conclusion that just as atoms, in which electric forces are in play, will emit light, i.e. electromagnetic waves, when violently disturbed, so nuclei should, as a result of violent collisions, emit radiation of a new kind. I have mentioned that, according to the quantum theory, light consists of definite particles, or photons: similarly the new radiation will contain a new kind of particle. According to Yukawa, these should be fairly heavy, of weight about 300 times that of an electron, or one-sixth that of a proton. Such particles of intermediate weight are now called mesons. Mesons were indeed found to exist in the cosmic radiation which enters the earth from outer space and whose origin is not yet completely understood. But if Yukawa's ideas were right, they should be expected to cause violent disturbances in an atomic nucleus if they passed through it, and

surprisingly this was found not to be the case. The difficulty was resolved when Powell discovered the existence of two different kinds of mesons, which he called 'pi' and 'mu' mesons. The heavier pi-mesons behave in every way just as Yukawa had predicted, and they are produced in collision of fast particles with nuclei. However, they only live a very short time (about a few thousand-millionths of a second) and then break up into the slightly lighter mu-meson and a neutral particle, which escapes detection. The mu-meson lives only a little longer (about two millionths of a second) and thus neither of these particles is found in ordinary matter.

It was expected that, having once identified the mesons, it would be a comparatively simple matter to follow through the ideas of Yukawa quantitatively, accounting for all the details of nuclear forces in terms of meson fields. The task proved extremely difficult and has not yet been accomplished. The difficulty comes from the fact that, whereas electric forces are comparatively weak, the interplay of nuclear particles with their meson fields is very much more powerful, and the resulting phenomena much more complicated. This is shown in practice by the fact that if a charged particle from one of the recent accelerators collides with a stationary particle it is quite as likely, or often more likely, to produce two or more mesons as to produce one. This is different from the collision between electrically charged particles, say electrons and hydrogen nuclei: in most collisions no photon is produced though sometimes one is, and the occurrence of more than one photon in a single collision is so rare as to be ignored in practice.

As a result of this the mathematical problems arising from the interplay of nuclear particles, and their meson fields, are so complicated that we are far from knowing the answers, and it is not yet sure even that the basic laws which we have attempted to formulate are anywhere near the truth. Collisions between nuclear particles and mesons are, however, now being studied in great detail, and, at least qualitatively, the results encourage an interpretation in terms of laws of the Yukawa type. This is a field in which further progress is impatiently awaited, but there is no indication yet how long it will be before we are sure of our ground.

The discovery of mesons had not come as a surprise, because Yukawa had shown that their existence was suggested by the

nature of the nuclear forces. But for all we knew they might well have been the last fundamental particle to be discovered. However, during the last few years this situation has been completely changed by the discovery of a number of new particles produced in collisions at high energies.

The first of these particles was discovered a few years ago by Butler and Rochester in Manchester, who observed, amongst the tracks of cosmic-ray particles in a photograph, two tracks which started from a point in mid-air with no apparent cause. Considering all possible interpretations of this observation, they came to the conclusion that these were probably two particles of opposite electric charge which resulted from the break-up of some neutral particle (which would not leave a visible track). This could not be one of the known particles, and the observation thus indicated that our list of fundamental particles was not yet complete.

Only one such photograph was obtained in the Manchester work, and one could not be sure of the discovery until it had been checked by more numerous observations. It turned out that more of these events could be found by taking the apparatus to the top of a high mountain, where the cosmic rays are less weakened by their passage down through the atmosphere. Once the equipment had been moved up for this purpose, a group of physicists in America and the Manchester group, followed by many others, obtained rapidly many pictures of such events, from which the nature of the particles could be identified beyond doubt.

It soon became clear that one was dealing with at least two different new particles, which, following the practice of labelling such new particles by Greek letters, were called 'lambda' and 'theta' particles respectively. The first breaks up into a proton and a negative pi-meson, the other into two pi-mesons of opposite electric charge.

It was also found that there exists a charged particle, now called 'sigma', which decays into a proton and a neutral pi-meson. One of these had, in fact, already been seen in one of the early Manchester photographs, almost at the same time as the first lambda track.

After this, new discoveries followed each other rapidly, as better methods were developed for studying such events. In this work much vital material came from photographic plates carried by balloons to altitudes of 100,000 feet or so, where one

is so close to the top of the atmosphere that most tracks are caused by the primary particles (mostly protons) of the cosmic radiation, or their direct products in collisions. This work has been facilitated by the use of thick stacks of the sensitive emulsion layers of many photographic plates, in which the track of a particle can be followed over an appreciable distance, and often to its end, no matter in what direction it happens to be travelling.

More recently many of the new particles have also been made artificially with the accelerator of the Brookhaven laboratory in Long Island, which yields particles of over 3,000 million electron volts; the latest machine to come into operation, that at the University of California, reaches energies of over 6 MeV, and this looks like superseding balloon flights as the main source of information for most purposes.

The list of new particles, as known to-day, is too long to be set out here, but some of the more interesting ones are the 'tau' meson, which breaks into three pi-mesons when it decays, and the 'xi' particle which decays into a 'lambda' and a 'pi' meson; as the latter is succeeded by a mu-meson, we have here a family of four successive generations, from great-grandfather to great-grandchild, all of whose members were unknown about twenty years ago.

A common feature of these new particles is that they are all unstable, and live on the average, only a very short time, so short that even travelling with nearly the velocity of light they would reach only a distance of an inch or so from the point where they were produced. This is just about long enough to obtain a good measurable track in a cloud chamber. (Some types live about a hundred times longer.) If there were any other particles with still shorter lifetimes, they could be detected only by circumstantial evidence, and it is quite probably that more such particles should indeed exist.

When these particles were first discovered, and when it was found that they are very copiously produced in sufficiently violent collisions, it seemed hard to reconcile their easy production with their existing for what is, relative to the amounts of energy involved, really a very long time. It was suggested that this difficulty would resolve itself if they could be produced not singly, but in pairs, at least two 'new' particles resulting from the same collision. This would mean that, if two of these particles met, their transmutation into more stable particles

should also be very rapid, but each one by itself could undergo this transmutation only with difficulty, and hence would survive longer.

It was therefore satisfactory that experiments with machines, in which one has more control over the nature of the collision which starts off the event than there is in cosmic-ray work, did confirm that particles are in general produced in pairs, and the absence of processes involving the production of only one of them now seems reasonably established.

It is clear that these discoveries have opened up a field which will require many years' work only to catalogue all the processes involving such new particles. After the complexity of the chemical elements and compounds had been reduced to the knowledge of atomic nuclei and electrons, and the nuclei accounted for in terms of protons and neutrons, physics has now again expanded to an extensive catalogue of apparently basic objects. The physicist will not rest until their relations are again reduced to a common simple principle, but we are as yet in the dark about the nature of this principle. It is not likely to take, as it did in the case of the atom and the nucleus, the form of describing some of these particles as composite, being built of smaller sub-units. They are more likely to be related in a more subtle way. But whatever the ultimate form of the general principle, there is little doubt that it should be possible to account for the various kinds of particles, the way in which they are produced in collisions, and the way in which they decay, forming complicated 'family trees'.

These new particles and a detailed description of pi-mesons and their effects form the centre of interest of what is now known as high-energy physics. It may well be that these two problems are intimately related and that progress with one of them will assist the solution of the other. If this conjecture were true the discovery of the new particles would have some bearing on the understanding of the atomic nucleus, and therefore on the understanding of matter as we normally find it, but even then it is not very likely that they would contribute to new ways of using the atomic nucleus for practical ends. This does not diminish the interest of the physicist in them or his determination to push the frontier of physics farther ahead.

Automation - Revolution or Evolution?

Austen Albu

CONTRARY to popular opinion, natural scientists when dealing with their own subjects are generally modest. They prefer the ivory tower of agnosticism to that more brash positivism by which some popular writers are prepared to make assertions and prophecies from very inadequate evidence. Because they are popularly credited with some degree of omniscience, however, their statements on matters of which they have no particular knowledge, such as sociology or politics, are frequently accepted as if they had a greater degree of scientific validity than in fact they have. In recent years the technologist, or applied scientist, has felt a special urge to express himself on these matters, no doubt because of his belated recognition of the social and economic implications of his work; but perhaps also because of a guilt feeling that first found its expression in the movement known as Technocracy which flowered in the United States in the heady atmosphere of the 'thirties. Overwhelmed at the economic disaster which had turned even professional engineers into apple-sellers, the devotees of this new philosophy and their counterparts in this country were convinced that their technological advances had solved all the problems of the production of wealth and that mass unemployment was due to the application of their inventions in a society unfitted to receive them. With naive enthusiasm they set about the task of shaping society in their technological pattern.

The war and the subsequent high level of industrial activity in all advanced countries, accompanied as they have been by great increases in the production of goods, without any serious difficulty in their consumption, destroyed the climate of thought which favoured these and many other ideas which were once popular; but recently a new wave of technocratic

ideas has been set going in the United States, as a result of new developments in manufacturing techniques and in the application of electronics. To the general public these developments have been dramatized by the coining of new words such as *Automation* and *Cybernetics*, by talk of a new industrial revolution and of completely automatic, workerless factories and, in the popular press, by exciting descriptions of Giant Brains and Robot Workers.

Most of the popular writing on this subject confuses two developments quite separate in their origins: that of further mechanization of industrial processes already highly mechanized and the rapid practical advance in control of processes and in computing machines made possible by the new science of electronics. The excuse for this confusion lies in the fact that the most radical advance is being made when these two techniques are used together. The most publicized advance in the field of mechanization has been the automatic transfer machine installed chiefly in motor car factories. In these machines the part to be machined, generally in the form of a casting or forging, after being placed by hand at the first station of the machine, is then passed automatically through a series of machining operations so that it comes out at the end completely finished. Previously the parts had to be handled by machine operators on and off separate machines, between which they travelled on conveyors. Although the widest utilization of these machines has taken place in the United States, the first automatic transfer machine was built by Morris Motors in the 'twenties and the most advanced plant in Europe is that of the nationalized Renault factory in Paris. In Russia there is a plant which makes car pistons automatically from the raw aluminium ingot; the casting process being automatically linked to the machining.

Passing material automatically from process to process is not new, as anyone who has watched a newspaper printing press will realize. It is obviously easier, and therefore much older, in the chemical and food industries, where the material being dealt with is homogeneous and in the form of powder, liquid or gas. For this reason chemical plants, oil refineries and bakeries have been largely automatic for many years. Metal products are more difficult to deal with although, in the production of tin cans, there is a constant manufacturing flow, from the original tinplate sheet to the finished can, so that the cans passing along the conveyors from machine to machine have

almost the appearance of liquid flowing in transparent pipes. It has been said that what is now new is the extension of automatic operation to the hard, heavy, awkward and unyielding shapes of engineering components. Its advantage arises out of the increased size and cutting speed of modern machine tools, which have greatly increased their costs and made it more and more important to ensure that they spend as little as possible of their time standing idle. The automatic assembly of components to form a finished product has not yet been carried very far, although there have been significant developments in the field of radio and electronic equipment.

The automatic control of processes has been going on for many years in some industries and takes two forms. The first is the providing of a pattern of instruction which the machine or plant will carry out with no other human intervention than the feeding in of raw material. One of the oldest of these forms is the Jacquard loom, first demonstrated in Paris in 1801, which weaves patterned fabric by means of a system of punched cards and which is still widely used. Copying lathes have long been in use which are capable of machining a piece of metal by following the contours of a master pattern. The automatic timing of certain processes in the chemical industry and in plastic moulding is quite common. The second form is the self-regulating control, through continuous adjustment, of some function of a process such as pressure, temperature or speed. It is this operation which has become known as 'negative feedback', because it relies on the adjustment of excessive or insufficient quantities as measured by information transmitted direct to the controlling mechanism itself. One of the oldest forms of this kind of control, apart from the large number to be found in any living organism, is the centrifugal speed governor of a steam engine. A more common form to-day is the thermostat which controls the temperature in an oven, a refrigerator or a car radiator. These are comparatively simple devices, but since the war there have been a number of developments which have made possible the automatic control of far more complicated operations. These derive from the work done during and since the war on guided missiles; particularly on 'servo-mechanisms', which are the devices by means of which the information measured and received by the control mechanism is translated into the appropriate action. The task of measuring the function which it is desired to control has also

been revolutionized by the development of sensitive electronic devices which can measure very small quantities very fast and whose reactions can be magnified so as to make them operate, through appropriate servo-mechanisms, relatively heavy control gear.

Because of its immediate impact on employment it has been the introduction of transfer machines into motor car factories which has created the greatest anxiety, particularly among the trade unions; but it is the extraordinary development of computing machines which is likely to have the more far-reaching effects, particularly when they are used in conjunction with mechanized factory processes. It is to this combination, still in the future, that the title of Automatic Factory will be most justly applied. The modern electronic computer operates on mathematical and logical principles developed by Charles Babbage at the beginning of the last century. Babbage's ideas were supported by the Royal Society and the Government of the day, but the difficulty of constructing a purely mechanical instrument and his refusal to restrict his ideas to designs capable of manufacture by existing workshop methods prevented his success. He built several machines, one of which was used in 1863 for calculating the life tables used by insurance companies, and parts of them are to be found in several museums, notably the Science Museum. The story of Babbage's work has recently been told by Dr H. V. Bowden in his book *Faster than Thought*, where he explains that it is through the writings of Byron's daughter, the Countess of Lovelace, herself an accomplished mathematician, that we are able to appreciate Babbage's genius. It was he who first thought of trying the system of punched cards used in the Jacquard loom for presenting numbers to his machines in a form they could understand, a method to-day in common use in accounting and tabulating machinery.

It is the development of electronics which has made possible the widespread practical application of Babbage's ideas. In place of trains of gear wheels, levers, ratchets and other mechanical elements of movement, each absorbing considerable power in friction and inevitably slow to operate, the modern computer uses a large number of mostly very small electronic components connected together to form a very large number of electrical circuits. Because the information fed into the machine has been broken down into the smallest possible units, and because each electrical circuit can perform one tiny opera-

tion in a mathematical or logical calculation in some millionths of a second, the total power required is not great and the speed of calculation is very fast. There are two stages in the operation of the most common form of modern machine known as the 'digital computer': programming, which consists of setting up the operating instructions which the machine will follow: and processing, by means of which actual figures are fed in and analysed, calculations made in accordance with the instructions already given the machine and the results recorded in any one of a number of ways. Where the problems to be solved are of great complexity, programming is a job requiring considerable mathematical skill, and this stage of the whole process may well take much longer than the actual computation. Between the mathematical breaking down of the problem into a form suitable for the computer and its actual presentation to the machine, there is the task of translating it on to punched tape or cards; and this work can be carried out by girls with the skill of typists or punched card operators. Where a series of caluculations has to be made a number of times it can be arranged for the programme to remain continuously in the machine, so that it can be operated by ordinary office personnel. Or machines can be made with certain types of calculation ('sub-routines' as they are called) permanently built in. In addition to carrying out operations such as addition and subtraction, the machines can store sets of figures and the results of partial calculations can be remembered for use at later stages in a whole calculation. There are a number of ways of doing this, the most common being by means of the magnetization of a metal drum or steel tape as in a tape recorder. A steel tape is also used to take the information from the punched paper tape and transform it into the series of electrical impulses by means of which the elements of the computer operate.

Machines of this type have chiefly been used in this country for scientific work, especially that connected with aircraft and guided missile design, but they have a growing use in the administrative and commercial fields. One application is the working out of a large pay-roll, taking account of different hours of work, rates of pay, overtime and bonus, National Insurance contributions, PAYE, and voluntary deductions. Information needed to calculate group bonuses can be stored and, when the other calculations for each member of a group are finished, the share of the bonus earned by each of them is

then added to his gross wage. Planning the supply of raw material and intermediate products to complete a production programme, cost and sales analyses and stock control are among the more obvious industrial uses. In the United States the use of computors in banks and insurance companies is growing fast and has led to further advances towards the automatic office. For instance, in one insurance company all the information about its clients' policies is stored on magnetic tape, so that an employee requiring information has only to dial a code number to have the information printed out on ticker tape on his desk. In the Pennsylvania Station in New York there is an automatic system for handling seat reservations, so that the ticket seller can determine automatically the space available without reference to diagrams or need to speak to another official. The American Airlines Inc. have carried the process still further, so that a clerk is able to ascertain space availability on any flight originating in New York during the following ten days by using a key system connected to a computer. If the required space is available, a light flashes on the clerk's desk and the reservation can be made by depressing a key. This informs the computer which automatically decreases the number of seats still available. In a store in New York selling men's suits a plastic tag, punched with holes representing the style, size and other details, is attached to each garment. These are thrown into a hopper at the end of the day and automatically provide information for a computer which works out the sales made and stock position.

Computers, which can be used for solving complicated mathematical equations, involving a number of variables, should be of great assistance in industrial processes, particularly in the chemical industry, where problems of this nature arise. Already it is possible to make and record automatically not only simple quantitative measurements, but also chemical analyses. A computer, using information received direct from measuring instruments situated at different points in the plant and from automatic analyses of the raw materials being fed into the plant and of the finished product, should be able in theory to make the necessary adjustments of pressure, temperature, speed of flow of materials, and so forth, to ensure that the plant operates automatically at optimum quality and quantity of output. This would truly be the automatic factory which could be operated by the push of a button and would continue

to operate without human intervention until another button was pushed. It is, however, unlikely to be a practical proposition for some time, not because of inadequacies in the control system or in computers, but because of lack of knowledge of the characteristics of large-scale chemical processes and plants. This emphasizes the important point that computers can do no more than what they have been programmed to do; they can only operate on formulæ which have been put into them by human beings; if the formulæ are wrong they cannot prevent the plant blowing up.

If the fully automatic factory is still some way off in the process industries, it is obviously still further off in the mechanical industries, where discrete components of greatly varying sizes and shapes have to be handled through a great variety of processes and finally put together in complicated assemblies. There are, however, a number of ways in which the principles of the computer are likely to be used in conjunction with mechanical operations. The automatic inspection of parts for size and other qualities is already quite widespread. A development from this is for the inspection device to be used itself for controlling the machine on which a part has been made and adjusting it for faults. Such an adjustment can be delayed until the device has made the sort of calculation used in modern methods of statistical control of quality or, alternatively, equipment can be arranged to remember a partial fault and hand it forward to the next operative machine to correct. A revolutionary new development is the automatic machining of parts on computer-controlled machine tools. The lines and curves and angles of an engineering drawing are converted by planning engineers into data which are transferred by a typist on to punched tape which is fed into the computer. The computer records on magnetic tape the movements of the tool or machine table necessary to produce the desired shape, and the tape is then used to control the machine. This system, by which a number of machines can, if necessary, be operated from one computer, is most valuable when the time taken by the human machine operator, in the 'perceptive' and 'reasoning' part of his task, is high compared with the time taken in 'motor' action. This is always the case with highly skilled work. It has been suggested that a computer could be used to receive sales information direct and convert it into the details of a production plan, thereafter operating machines which automatically draw parts

from store and send them into the production lines for automatic machining and assembly. It is difficult to believe that this would be economically worthwhile for any but the simplest products, although undoubtedly some steps in this direction will be tried out in suitable industries.

Most of the developments in manufacturing method to which the name automation has been given are no more revolutionary than, to mention a few twentieth century developments, the mechanical stoker, the automatic loom, the original Ford conveyorized system of motor car production, the automatic telephone exchange, the manufacture of synthetic yarns and plastic mouldings or the introduction of quick-drying cellulose and synthetic paints on car bodies and furniture. They are advances, no doubt at an accelerating pace, in the art of the production engineer and in the equipment available to him, but, unlike some previous advances which have tended to make man the slave of the machine, these are more likely to free him from that bondage. Modern mass production industry, with its emphasis on quantity and repetition, has tended to make the worker merely a machine feeder or an assembler repeating the same motions hundreds of times during the day's work. It is this aspect of work which has engaged so much of the attention of the sociologists as well as of Charlie Chaplin and René Clair. Previous mechanization has more and more removed the hard, physical labour from this sort of work, but it has kept the drudgery of the human spirit. In the new methods most of the machine feeding and lever pulling will be done automatically and, as automatic inspection and process control progress, the need to sit hour after hour watching articles for occasional faults or dials for occasional deviations will disappear. Apart from the gain in human happiness, there will be an improvement in the quality of work, for it is known that repetition is one of the causes of fatigue, the effects of which are greatest in the performance of the mental parts of a task, causing mistakes and irregular work.

The result inside a given factory will be that the number of unskilled and semi-skilled jobs will decrease, but there will be a growing need for first-rate mechanics and electronic technicians for setting and maintaining the machines. The tendency for what used to be called 'non-productive' staff to increase will grow because much of the work previously done by men on machines will be done by planning engineers and computer

programming staffs. The number of supervisors and junior executives required will also increase, but they will be more in charge of machines than of men. They will be less like foremen and more like shift engineers in ships or power stations or chemists in charge in chemical plants. The tight relationship between separate parts of the productive process and its high speed will call for rapid communication between the staffs of different departments and a high level of collaboration. When men and women performing routine tasks are few and technicians and highly skilled mechanics co-operating in responsible work are many, human relationships in industry will undergo a salutary change. 'Man management' based on the psychology of the crowd should give way to more democratic behaviour based on mutual respect. Obviously these changes are going to involve a large amount of special training and, until adequate numbers are produced from new recruits specially trained at technical colleges or in industry, there will have to be a good deal of training and up-grading of semi-skilled workers, a process which will create a number of problems for the trade unions, both of differentials and of demarcation.

The speed at which these changes are likely to take place in this country will be largely determined by the availability of scientists, technologists and technicians capable of designing the new machines and of planning their use in industrial processes. At the present time there is a desperate shortage of such staff. This is to a large extent due to the defence programme, although that itself is speeding the pace of development in many fields with industrial applications; while National Service is providing a basic training in radar for a number of young men whom industry can afterwards train as electronic technicians. The daily papers and the technical press contain pages of advertisements for graduate engineers and technicians, and it is clear that, in spite of the doubling of the number of graduates in science and engineering since the war and the very much greater increase in the numbers awarded Higher National Certificates in engineering and other technologies, we are still very short of the numbers we require. Many of our ambitious plans for industrial expansion, in atomic energy, on the railways, in coal production as well as in manufacturing will be held back because of this shortage, unless a much more sustained drive is made to expand technical education, at all levels, in this country.

It is largely for this reason that the fears sometimes expressed about the effects of automation on employment are without foundation. The truth is that the shortage of trained staff is likely to keep its development well below the pace at which it could be economically and sociologically absorbed. There are, of course, other reasons as well. Some of the new machines need a very high level of capital investment and the scrapping of plant in which much money is already tied up. On the other hand, it is not necessarily the case that the capital costs of the new plant, per unit of output, are greater than those of the plant it replaces. New methods of manufacture, the standardization of machine elements, the smaller space occupied by some new equipment, may in fact result in capital charges becoming a falling element in costs. Nevertheless, the total amount required to convert, for instance, a whole motor car factory to transfer machining is substantial. Developments of this type are only suited to the mass production industries and are less likely to affect the capital goods industries, which form a higher proportion of our output compared with the United States, and on which our exports will increasingly depend.

It is not, however, the case that all the new developments are only suited to the giant firm. Small firms may benefit from the sub-contracting of computer services, whether they are used for office work or for the provision of control tapes for automatically controlled machine tools. Many of the new electronic devices are capable of development and manufacture by quite small firms consisting of groups of scientists and technicians, with a few skilled men, using mostly standard components which are now readily available on the market.

One of the hoped-for results of increasing mechanization is increased leisure, and this will increase the demand for other kinds of work, both in services socially provided, such as health and education, and in travel, holidays and entertainment. Even to-day little more than a third of our working population is employed in manufacturing industry.

Where difficulties are likely to arise is in the uneven speed of application of the new techniques. If the rising output of the mass production factories is to be absorbed, wages and salaries must rise, not only in the industries concerned but in the whole economy. The remuneration and working conditions of workers in these industries will tend to rise faster than in trades which cannot so quickly take advantage of the new methods. There

is, for instance, already a marked difference between the engineering workers in the Midlands and those in the heavy engineering establishments on the North-East coast, which automation will increase. The introduction of labour-saving machines will give rise to problems of adjustment within individual factories, but these should not be difficult of solution on two conditions: first, that there is a continuance of full employment both nationally and in the district in which the factory is situated; secondly, that the trade unions and their shop stewards are fully consulted on the changes, agree to the new conditions of employment which they make necessary and participate in the administration of schemes of re-training and up-grading of workers. It goes without saying that they will also have to be satisfied that the standard of living of their members will rise as a consequence of the changes; but from recent experience it does not seem as if this will be difficult in the industries in which the greatest mechanization has so far taken place. There are no industries in this country as dominant as the automobile industry in the United States and no town so dependent on one industry as Detroit, so that the problem of local unemployment should not be as serious as it is there. The great variety of industries in the Midlands should provide some cushion against the results of too rapid a development of new manufacturing methods although there might be difficulty in Coventry. On the office side there is at present a serious shortage of trained staff and the growth of demand by service occupations will certainly make up for any redundancy caused by the installation of computers. On the national level the growing use of computers for the processing of economic statistics may speed up the provision to governments of the information they need in order to deal with sudden changes in the economic situation and so assist in the maintenance of full employment. One type of machine is being developed for the setting up of models of economic behaviour, and is already beginning to provide economists with answers to questions they have not so far been able to obtain.

Looking into the more distant future, there are signs of a social problem which might have serious effects if steps are not taken to deal with it in time. In a paper read to the recent conference on the Automatic Factory, held by the Institution of Production Engineers, Lord Halsbury drew attention to the probable development of three types of labour. The old

drudgeries of routine work, whether of factory or office, would be replaced by machines under the supervision of technicians. Heavy manual work on creative tasks, such as civil engineering construction, forestry and oil drilling, will still occupy tough young men who get satisfaction out of the use of their strength through their hands and the high wages that they will receive for their work. There remains a third class of labour – that of those engaged in the dirtiest, hardest and most dangerous occupations, such as coal-mining and stevedoring, and this class may be destined to become increasingly isolated socially and psychologically from the rest of the community. Anyone who has studied the sociological background of strikes in the coal mines or the docks will realize the justification for anxiety on this score. Technology may well leave us with a cross-grained minority of those on whom has fallen the residue of the world's drudgery in a majority world of engineers, administrators, scientists and artists. If the groups which comprise this minority are excluded from the improvements in status and work conditions enjoyed by the majority, this will tend to increase the already strong emotional bonds within such groups and their feelings of isolation from those outside; and this will be happening at a time when the need for closer co-operation between different groups in society will be growing for economic, as well as social, reasons. It is against the new divisions that it may create in our society, rather than its supposed economic danger, that we should be on our guard as the many sided developments which go under the name of automation spread through industry; and every effort of scientific research should be made to carry their benefits to those whose work at present appears to preclude them.

Towards Tektopia

Our Increasing Dependence on Energy Slaves

A. R. Ubbelohde

'WHAT an age of impruvment it is!' exclaimed Mr Jorrocks when speaking about the use of the American reaping machine to cut faggot sticks. Surtees was writing around 1843, but his hero's comment could have been made at any time during the first industrial revolution. Now, 'improvement' is widely held to have passed into a new phase, a second industrial revolution. One thinks of Britain, and of many other nations of the world, at the beginnings of a new flood tide of increased mechanization of the necessities and arts of living, increased automation of peace and war, more grandiose applications of the power of science, and so on, boom without end. The human imagination rather falters at a really thorough consideration of the things to be expected say thirty years hence. In this perplexity, experience of the first industrial revolution can in some ways be a handicap. As in past times of rapid change, there may be periods ahead of difficult adaptation and these may lead to economic, social, and political stresses. But in dealing with such stresses the only safe legacy from the first industrial revolution is the firm resolve never again to let rapid technological progress impose excessive sacrifices on human ways of living. In their details, the various measures developed for counteracting the harshnesses of the older industrial revolution may be useless or even harmful when dealing with the impact of the newer processes of change.

Since the consequences of modern technological progress seem inescapable, it is imperative to attempt some kind of survey, both in self-defence and as a help towards smooth adaptation. At the outset of such a survey it is best to realize that the number of new developments to be considered is confusingly large. This is illustrated amongst many other examples

by a recent survey of 'The New Industrial Revolution' (*Financial Times*, July 8th), which balances more familiar lines of thinking about themes such as:–

- The Changes in our Economic Circumstances and in the Pattern of British Production.
- Monetary Incentives.
- Profit Sharing Schemes.
- Inflationary Pressures.
- The Rate of British Capital Investment.
- Domestic Efficiency.
- New Management Techniques.
- Joint Consultation.
- Work Study.
- Trades Unions.

with considerations about activities in which technological progress is at present particularly dynamic such as:–

- Silicones.
- Plastics.
- Synthetic Rubber.
- New Metals and Alloys.
- Synthetic Detergents.
- Man Made Fibres.
- Radio and Television sets.
- New Mechanical and Electronic Aids to Factory Operation.
- New Methods of Transport.
- New Methods of Selling and Marketing.
- New Methods of Building.
- New and Improved Sources of Driving Power, including Nuclear Power.

In the profusion of new possibilities, broad integrating ideas can be of great value in examining our present situation. Allowance for the obvious limitations of broad simplifications can be made subsequently.

One powerful way of measuring the technological advancement of a community is by counting its population of energy slaves. Such procedures have been discussed in greater detail elsewhere,* but the basic ideas are quite simple. Save perhaps in certain delectable regions of this world, men everywhere show an unwearied urge to master their environment. Deep down, the drive behind modern technological progress stems from a twin urge towards more knowledge and towards more power. Physical power over matter is subject to energy laws which have gradually become known and accepted as part of

* *Man and Energy*, by A. R. Ubbelohde. Hutchinson, 1954.

the structure of nature. Knowledge of these laws permits quantitative measurements of the energy available for 'getting things done'.

For the particular integrating ideas to be discussed here, the point to be made is that mastery over matter, in the great diversity of ways now becoming familiar to us, always involves energy transformations. The stone that is picked up and thrown at an enemy, the plough that is dragged by animal effort, the petrol motor that uses the energy stored in hydrocarbon fuels as motive power, are but a few out of innumerable instances of purposeful transformations of energy.

It is highly convenient to have a common measure for all these transformations; any form of physical energy available for human application can be measured in terms of mechanical work. A great variety of 'machines' have been invented in more than one civilization for redirecting mechanical effort. But machines will not run of their own accord. Perpetual motion is not possible and, however ingenious the construction of any machine, a prime mover must supply energy continuously to drive it.

Energy Slaves. Our own age is remarkable for the creation of energy slaves to drive machines. In all civilizations prior to our own prime movers were nearly always animate. This set a natural biological limit to technological planning. To drive any machine you had to harness a horse or an ox or an ass, or, if the work was intricate and not too heavy, human effort could be harnessed even more readily. The construction of the first practical steam engine around A.D. 1712 marks a much more fundamental emancipation from slavery than is sometimes realized. Since that time it has been possible in principle to do completely without animate energy as a source of prime movement. Instead of human slaves, energy slaves are now available to bear the burdens of hard labour.

There has been an enormous increase in the world population of energy slaves since A.D. 1700, but it is still very unevenly distributed. Accurate counts of its energy slaves are a guide to the material welfare of a community. Comparative ratios of energy slaves to animate members in different communities can be a guide to their relative technological advancement.

Advance towards Tektopia. A quantitative census of energy slaves gives very practical information about any community; from a more philosophical standpoint, it must also be asked

where this constant striving for new technological advances is leading mankind. In the past, philosophical considerations about the ideal state such as Plato's *Republic* or More's *Utopia* were guided by the fact that in these hypothetical communities material burdens had to be borne by animate effort of some kind. This imposed very real physical limitations to organizations discussed by these older writers. With the possibility of including a large number of energy slaves in a state, the new Utopias are fundamentally different from the old. It is convenient to mark this change by a new term, 'Tektopia'. Tektopias may be defined as ideal states or Utopias containing a large proportion of energy slaves to human beings. In Tektopia there are no obvious biological or physical limitations arising merely from the need to muster sufficient physical power to achieve a set purpose. But all kinds of limitations of the human spirit remain to be mastered.

Energy Slaves in Different Communities. Practical engineers who built and sold the first steam engines nearly 250 years ago used rough quantitative comparisons between animate prime movers and the new energy slaves. Being Englishmen, they chose the labouring capacity of a horse as the basis for comparison. The standard (British) horse is considered to be capable of lifting a burden corresponding with 33,000 lb. through a height of 60 feet every hour. The physical labour a man can exert varies with the nature of the job; it can be about one-tenth that of the horse. By various physical formulæ, all other forms of mechanical effort can also be expressed in common power units. This makes it quite convenient to compare the population of energy slaves in different countries by comparing power units used per head of human population.

For reasons too involved to detail here, energy stored in various forms with coal, oil or electricity has to be included according to appropriate rates of exchange, before completing any comparisons between the energy slaves in different communities. However, for some of the communities most interesting at the present time the full power census covering all forms of physical energy is not always known. A less balanced but more accessible basis of census is the electrical power used per head of population. Roughly 1 horsepower-hour = $\frac{3}{4}$ kilowatt-hour = 10 manpower-hours. For the table given below, the information has been left in the form of kilowatt-hours of electrical energy used every year per head of population.

TABLE I

Kilowatt-hours of electrical energy consumed in 1951 per head of population per year

Group I		*Group II*	
Norway	5500	UK	1133
Sweden	2764	West Germany	1052
Switzerland	2460	Benelux	953
USA (1950)	1872	Austria	947
		France	938
Group III		*Group IV*	
USSR	?	Portugal	120
Italy	620	Greece	95
Denmark	577	Turkey	42
Irish Republic	328	Indian Union	21
		China	?

This table brings out certain leading features about the relative advance towards Tektopia of some real communities. Electric power is used both for driving heavy industrial motors and the like, and for the innumerable small and fractional horsepower electric motors, which have replaced the horse and ass and ox and human labour in a great variety of jobs. Since the figures in Table I do not include power generated privately within an industrial group, they understate the full difference amongst users. Natural advantages in supplies of hydro-electric power tend to exaggerate the apparent lead of the Scandinavian countries and of Switzerland in the use of electric power. Next to these the United States has a striking lead in the number of energy slaves at the service of each human worker in the factory or in the home. According to other estimates more carefully weighted than mere records of electrical power consumption, each American worker has three times as many energy slaves at his disposal as the most advanced European worker.

The Western European nations form a fairly closely matched second group. In these highly industrialized European countries the ratio of energy slave to human is now fairly uniform. Probably this reflects the fact that economic competition within this group of countries is fairly effective and that no single nation can go very far in taking the lead or in falling behind, without serious strains arising internally and internationally. The proportion of energy slaves has a marked

effect on the economic practices and on the material welfare of the different communities, and there seems to be no reason of principle why the European should not pull up towards the American and even outstrip him. It takes time, however, to build a sufficiency of stations generating electric power. The aggregate population in the middle group of technologically advanced countries is about 230 m. Tripling even the present rate of consumption of electrical energy will take many years, unless the development of nuclear generating stations and the building of new distributing grids rises steeply. Since in addition to building more generating capacity, various consuming installations likewise take time to build up, it may be anticipated that the present relative degree of advancement towards Tektopia is not likely to change catastrophically in the next ten years.

A third group possibly includes countries of the USSR. The attainment of anything like the American proportion of energy slaves requires massive investment in the heavy industries. It is often stated that such massive investment is taking place, but meaningful comparative figures are hard to obtain.

In its own way the fourth group presents particularly striking problems. By far the largest fraction of the earth's inhabitants, approximately 1,700 m. head of population, belongs to communities in which the proportion of energy slaves still is very small indeed. Here any increases of power consumption are likely to compete much more immediately with the burdens of labour at present carried by the human inhabitants. It will require constant vigilance in the leaders of such countries to avoid the kinds of strains and conflicts well known in Europe during the first industrial revolution. Quite apart from risks of local adaptation stresses, if the advance towards Tektopia is to become more widespread world power demands will jump to a surprising extent.

It seems safe to say that only the development of reserves of nuclear energy could possibily provide sufficient power to allow even a moderate levelling in the advance towards Tektopia over the world as a whole.

World Energy Reserves. Table II indicates some of the present known reserves of energy of various forms. In countries with large energy demands, reserves of coal, oil and hydro-electric energy have been prospected intensively. Solar energy, tidal energy and wind energy may offer possibilities in certain situations favoured geographically, but often the parts of the

earth most suited for power generation by such comparatively untried means are deficient in the population that could use them, and the needful capital investment may be high. Nuclear energy reserves form a separate class where the world picture is hard to draw at present.

TABLE II

World Energy Reserves in Q

1 Q = 10^{18} British Thermal Units (BTU)

	Coal	*Oil*
USSR	10	1·3
USA	7·6	0·5
China	6·0	?
Canada	2·0	—
UK	1·0	—
Others	7·0	3·2

Attention needs to be drawn to the highly vulnerable situation of Great Britain with regard to energy reserves. Represented in the rather crude but quite basic way discussed here, the end results of the first industrial revolution are clear. The British proportion of energy slaves marks a degree of advancement towards Tektopia at present well behind that in the United States, and more or less level with its European neighbours. The vulnerable situation in years ahead arises from the fact that less and less of the energy to supply these slaves seems likely to be drawn from reserves situated within these islands. Political economy suggests fairly obvious and quite vital consequences of our ever-increasing power needs. Either we must continue to import stored energy in the form of oil,* coal, electric power, and various nuclear fuels, or the whole energy consumption in the British economy will have to be drastically reduced, bringing grave suffering and incalculable hardships to many innocent people at present often quite ignorant about this situation. Considerations of this kind make it more urgent to press on with nuclear power projects in this country than in many others whose present degree of advancement towards Tektopia is otherwise similar. To meet emergencies, reserve stores of nuclear fuel are also highly desirable. It will be clear,

* Before the war, oil supplied 6 per cent of the total gross energy consumption of British industry. Now the figure is 15 per cent and likely to increase.

also, that the paramount interest of this country in liberalizing world trade includes free trade in energy reserves.

Human Obstacles in the Race towards Tektopia. In what has preceded, it was provisionally accepted that the advance towards Tektopia is relentlessly one-way. Even if it seemed to us desirable to control or to slow down rates of advancement in certain directions, no country neighboured as we are can contract out from the broad trend of technological progress. Human obstacles and limitations may, however, operate to varying degrees, especially in more remote communities; in the years ahead these must eventually string out some of the world-entry of runners in the race for technological progress.

A very much simplified summary of possible human obstacles in the advance towards Tektopia can be given in terms of three main influences. The first two are sometimes described under the word 'automation', whilst the third concerns problems of adaptation to change. (i) Energy slaves are constantly carving away and undermining the lower levels of the pyramid of human craftsmanship. (ii) As the proportion of energy slaves to human beings increases, ever greater demands are made on higher supervision and management. (iii) The ever-increasing proportion of energy slaves to human beings continually modifies patterns of human society which in previous ages changed much more slowly. Because of the rapidity of change, political and social adaptation can from time to time become very difficult, and can call for catastrophic adjustments.

Automation. The strongest recommendation of energy slaves is that they replace animate energy of some kind. New developments become possible in more advanced stages of organization that would have been unthinkable had the replacement not occurred. But, unless the human labour displaced can benefit by the replacement and quickly find alternative activities, luddite conflicts are inevitable. Looking back at the first industrial revolution, it is easy to understand why there should have been distrust of the clumsy steam engines; these only needed coal to feed them, whereas the displaced labourers needed bread. Now, possible conflicts between energy slaves and human workers are mostly at a much more complex level. Except for the most intricate tasks which are difficult to hand over to energy slaves, it has long been unprofitable in the more advanced communities to use human energy unsupported by inanimate energy to do the hard labour. What is new is the development of methods

for controlling the applications of machines by electronic means. Essentially, the machine on the task registers certain simple messages in physical terms, and these are fed back to an automatic control of the machine. The outcome is that quite costly, because quite intricate, manufacturing operations, such as the precision drilling and machining of motor engine parts, can be handled by energy slaves with far less human control than heretofore. Whilst the capital cost of such automatic factory installations is high, when a large output of high precision manufactures is required automation can pay handsomely. Skilled engineers who used to operate the machines now electronically controlled are quite naturally uncertain whether to welcome this new development or to oppose it because it displaces their functions.

Experience has shown that there are rewards in accepting technological progress and that it is quite reasonable and indeed essential to share out the increased productivity resulting from new advances. But to give proper force to this experience there must be conscious, careful, and continued education of all those concerned. Failing such education, countries such as the United States, where there are fewer unhappy deep-rooted memories of earlier cruder conflicts between men and energy slaves, are likely to adapt themselves much less wastefully to automation than for example Britain. One of the reasons why the newer industries are relatively much more prosperous in Britain is because they are less haunted by bogies from the past that inhibit productivity.

Communities at present less developed technologically do not have unhappy memories of past conflicts with energy slaves to obstruct present adaptation. Other obstacles of temperament and capacity and purpose may however reveal themselves. There is no guarantee that the genetic possibilities of mankind will throw up everywhere in the world men and women suitably adapted to the newer demands of intensive technological development.

Education for Tektopia. Technological progress seems inevitable. This makes it quite essential to plan our systems of education so as to promote constant adaptability. But to say that we must adapt ourselves to change, to preserve even many of the good things we have inherited, in no way answers some of the profounder problems that harass the advance towards Tektopia. One question is whether there are limits to improving

the material standards of life beyond which further additions merely clutter up and choke other more spiritual activities of balanced human beings.

A second question refers to the integration of lives in a community. The technological conditions for maintaining a large population of energy slaves impose patterns of living which may be not worth the benefits conferred. Excessive integration may make a community particularly vulnerable to shocks and stresses from without and to old age and attrition from within. Tektopia in peace may be troublesome enough, but Tektopia in war threatens to involve the extermination of all except the most servile or the least developed communities. In war, it may be real good fortune to be less highly integrated, and so less vulnerable, than more advanced communities.

A third question refers to our increasing dependence on experts. Economic decisions, even when these are still open to free choice politically, are becoming ever harder to examine by the non-expert. An insidious transfer of final decisions to experts may, and indeed must, progressively undermine the aims of political freedom and a broadly based democracy.

What can be stated most clearly with regard to problems of the kind just outlined is that the advance towards Tektopia is not automatically progressive. New demands are being made on the spirit of man; these are centred in a whole range of categories not covered by scientific and technical aspects of the advancement. As material possibilities become more distracting, manners and religion are likely to be tested more searchingly. With the growth of the material resources of a community, education seems likely to make ever greater absolute demands on the national income. A rough quantitative rule would be that the *proportion* of the national income spent on education should remain constant. Such a rule must be tempered by the thought that decentralization and experimentation, which can do so much to foster good education, run counter to a tendency to over-centralization characteristic of highly integrated communities. Technological integration is a necessity in many enterprises, but it sets a constant bad example of over-centralization in other matters. In the advance towards Tektopia, effective decentralization of administration in all the varied activities of a community needs continued encouragement and conscious planning.

The Imperfections of Man

P. B. Medawar

EVOLUTION is one of the subjects upon which laymen have long felt themselves entitled to express an opinion; formerly, the opinion that evolution did not happen; latterly, that it does not happen in the way that biologists now suppose. The chief among several causes of their present discontent is approximately as follows. Biologists believe that evolution has come about through the action of material forces, in the sense that it does not unfold itself according to a preordained purpose or superimposed design. To laymen, an argument which takes no account of design or purpose or Aristotelian Final Causes is utterly unsatisfying and implausible. How can mere unguided material forces be responsible for the miraculous optical engineering of the eye; for the exquisite functional aptitude of a bird's wings; for the almost finicky precision of mimicry? Is it not going a little too far to impute these splendid accomplishments to what Bacon called the 'casual felicity of particular events'?

These are intelligible complaints, but they are founded upon a misconception, namely, that evolution is a perfectionist process. The eye, for example, is beset by chromatic and spherical aberration, and is not correctly centred along its optical axis; Helmholtz, the grand master of physiological optics, said that an optician would be ashamed to make an instrument with such elementary physical faults. Many of the perplexities of laymen might be set at rest if it could be shown that evolution is very much a fallible, makeshift affair, and that loss of fitness in one regard is often the charge for some more-than-compensating gain. I choose the imperfections of man as the subject of this essay, because man's superlative biological status is hardly to be questioned, and shall take three examples of his falls from biological grace: his susceptibility to hæmolytic disease of the newborn; the mechanical shortcomings of his upright carriage; and the ineptitude of wound healing in injuries of his skin. Of

these, the first is familiar enough, and I shall deal only with its broader aspects; the second is well understood but not yet widely known; and the third will be unfamiliar to all except a few specialists in the theory of wound healing.

* * * *

Hæmolytic disease of the newborn is the general name given to a variety of affections (kernicterus, icterus gravis, hydrops fetalis), which are marked by grave and sometimes fatal abnormalities of the blood and blood-forming organs; its interpretation, which we particularly associate with the names of Levine, Landsteiner and Wiener, is one of the great triumphs of modern clinical biology. Briefly, it is an *immunological* disease; it depends upon the active immunization of the mother against blood group substances (chiefly those of the Rhesus and Kell systems) absent from her own tissues, but present in the tissues of her child. Like many forms of allergy and hypersensitivity, and like the reaction that forbids the use of one person's skin to repair another's, hæmolytic disease can be described as a miscarriage of immunological justice – a harmful and apparently wanton aberration of what is properly and primarily a mechanism of defence.

Hæmolytic disease of the newborn is a peculiar menace to human beings for the following reasons. If it is to occur at all, two qualifying conditions must be satisfied at the outset. First, the antibodies which are the chemical effectors of the immunity reaction must be able to pass from the mother's circulation into the circulation of the unborn child. In effect, this means that the membranes which separate mother from fœtus must be of such a kind as to let the antibodies through. This first condition is satisfied by rabbits, rats and mice, and also by human beings; but not by cattle, sheep and horses. Second, the fœtus must reach before birth a stage of development at which the immunizing substances present in its blood corpuscles have reached maturity, for if they are still undeveloped at birth the mother can have no normal opportunity to become immunized against them; and even if the mother were artificially immunized, the antibodies so formed could not attack the fœtal blood. This second condition is satisfied by cattle, sheep and horses, and also by human beings, but not by mice and probably not by rats.

On the face of it, mice should be specially liable to be

immunized by their own young, for a female mouse may give birth to a quarter of her own body-weight of young in a single pregnancy and to ten times her body-weight in a lifetime; furthermore, antibodies formed in the mother have direct access to the embryos within it. But it seems to be impossible to give mice hæmolytic disease, even when their mothers are deliberately immunized against the red blood corpuscles of their young. Mitchison attributes this to their extreme immaturity at birth; if the degree of maturity of red blood cells is taken as a yardstick, birth in mice takes place at a stage equivalent to a human embryo that is still six months from term. Conversely, cattle, horses and sheep can only get hæmolytic disease after birth – a stage at which it is clinically manageable – for it is only at birth that antibodies pass from the mother to her young, in the colostrum, the first watery milk.

Human beings qualify on both counts: maturity at birth and the ability of antibodies to gain access to the unborn young. Nor is this the whole story. Hæmolytic disease can only occur if the members of an interbreeding population are dissimilar in their antigenic make-up. If all human beings were Rhesus-positive or Rhesus-negative, it is obvious that they could not get hæmolytic disease (or suffer from transfusion accidents) as a result of immunization by the Rh antigens. But they are, as it happens, most highly diverse with regard to the antigens present in their red blood corpuscles. About one in six Englishmen lack the most mischief-making antigen of the Rh series, viz. D or Rh_0; about one in ten possessess the Kell antigen.

We may now ask, what advantage do human beings enjoy which compensates, or more than compensates, for their vulnerability to hæmolytic disease? It is clear that man's embryological advantages, if such they are – a long gestation period, coupled with a form of gestation which allows beneficent as well as harmful antibodies to enter the fœtus – could be enjoyed with impunity if the entire population were either all positive or all negative in respect of the blood group substances Rh and Kell. The question therefore resolves itself into asking: Why, then, have they not become so? Unfortunately, the answer is not known; it is merely being groped after.

Roughly speaking, there are two kinds of reasons why a population should be polymorphic, i.e. should be subdivided into variant types of which even the least frequent is far too frequent to have originated merely through the recurrence of

mutations. The first is that heterozygotes (which carry and therefore propagate a gene, but do not necessarily reveal its presence) should stand at some special advantage relative to homozygotes. Contrary to all superficial appearances, this appears to be true of the blood affection known as 'sickle-cell trait', the analysis of which provides a most noteworthy example of a combined operation in genetics, chemistry, anthropology and clinical medicine.

Briefly, 'sickle-cell trait' is an affection in which the red cells of deoxygenated blood adopt a sickle shape. Pauling and his colleagues showed that it is due to the presence of an abnormal variant of adult (as opposed to fœtal or infantile) hæmoglobin. Sickle-cell trait appears in about 9 per cent. of American negroes, and in a percentage varying from 0 to 45 per cent. in communities of African negroes. Its inheritance, worked out independently by Neel and Beet, is governed by a Mendelian dominant gene, and sickle-cell trait (a condition which is not harmful in itself, nor even appreciably disabling) is its heterozygous or hybrid form of expression. Individuals who are homozygous for the sickle gene, however, suffer from a grave and sometimes fatal anæmia, and few of its sufferers live to reproduce.

The frequency of the sickling gene is far greater than can be accounted for by mutations in the face of powerful selection against the homozygous form. According to Allison, the reason why it flourishes is that the heterozygote is endowed with a specially high resistance to subtertian malaria; in areas of the world where malaria is hyperendemic the gene is therefore kept in being by the high selective advantage of the heterozygote; elsewhere it is going or gone.

No such neat and rounded story can be told of blood group polymorphism; indeed, it was at one time thought (and by geneticists feared) that the subdivision of human beings into the blood groups A, B, AB, O was entirely capricious, in the sense that an individual's blood group had no bearing on his fitness to survive and reproduce. Workers at the British Postgraduate Medical School now find that membership of blood group A is associated with an increased susceptibility to cancer of the stomach, and membership of group O with a greatly increased susceptibility to peptic ulceration. Blood group polymorphism is thus certainly not a matter of indifference, though its import is still obscure. But, so far as I am aware, no one has yet been able to associate the subdivision into Rh blood types

with anything except the unqualified incubus of transfusion accidents and hæmolytic disease.

It is possible, then, as Haldane has suggested, that the diversity of Rh blood types represents a second kind of polymorphism – that which is merely transient, a necessary intermediate stage between the elimination of one type or the other. This interpretation is borne out by the existence of rather bold inequalities among different races and nations in the proportions which belong to the several groups. The number of Basques who are Rh-negative falls between one in three and one in four, but Levine and Wong found only one Rh-negative individual among 150 Chinese, having been led to their enquiry by the significant observation that hæmolytic disease in China is very rare. If the interpretation is true, then hæmolytic disease could be explained away as a transient genetic ailment of mankind, but fortunately we can look forward to something a little more expeditious than an evolutionary cure.

* * * *

Man's upright carriage may be a constant source of moral satisfaction, but it has certain serious mechanical drawbacks. Man is unique among four-legged animals in being able to stand erect, on the flat of his feet, and to balance himself in that position. (Even gorillas do not stand upright more than momentarily, and they walk not on the flats but upon the outer margins of their feet.) The shape of the backbone has changed accordingly. In all other animals, with unimportant exceptions, the backbone is more nearly horizontal than vertical, and it takes the form of a single unkinked or uninflected arc from neck to tail. The 'vertebral column' is not a column at all, but is more like a cantilever having the four legs as piers. The vertebral column of a human being is no longer a simple uninflected arc; it bends slightly forwards in the neck, slightly backwards in the thoracic cage; forwards again in the lumbar region, the small of the back, and backwards in the fused vertebræ that form the sacrum. That is the mature pattern; in development, the neck flexure appears somewhat before birth, and the lumbar flexure between the ninth and eighteenth months of age.

An upright stance imposes new and peculiar stresses upon the spinal column. The support of weight imposes a force acting down the vertical long axis, which tends to compress the

vertebræ upon themselves. The angle of their apposition is responsible for a shearing force between the bottom-most lumbar vertebra and the sacrum; and general flexional strains become very apparent when stooping to pick up weights. To cope with these new forces (for such, in an evolutionary sense, they are) man inherits only the standard outfit of muscles and ligaments, and the muscular bracing of the neck and lumbar region leaves much to be desired.

What suffers from the wear and tear of habitual use is not, primarily, the vertebræ themselves, but the tissues lying between them. The bodies of the vertebræ are not set against each other face to face; on the contrary, about one-quarter of the total height of the column (more in the lumbar region) is occupied by peculiar solid intervertebral joints. Each joint forms a so-called intervertebral disk – a central nucleus of semi-fluid consistency, which embodies or represents the remnant of the embryonic notochord; contained within a tough fibrous ring, the annulus, in which the fibres are disposed cylindrically in coaxial rings; the whole being bounded above and below by flat cartilaginous plates. The whole organ has been described by one of its leading students, Ormond Beadle, as a hydrodynamic ball bearing.

The bearings may give in a variety of different ways. Under repeated flexion of the spinal column when it is taking weight, the nucleus may gape through a weakness in the fibrous ring which normally contains it, press against the posterior ligament, and even encroach upon the spinal canal. Alternatively, as if by the insistent action of 'telescoping' forces, nuclear matter may break through perforations in the cartilaginous plates and obtrude into the vertebral bodies, which are made of spongy rather than of compact and concentrated bone. In recent years, the opinion has been gaining ground (perhaps too rapidly) that many disabilities which have been loosely classified as sciatica, lumbago and vague rheumaticky back pains are due to abnormalities of the intervertebral disks; the immediate causes of pain may still be debatable – for example, as to whether or not mere chronic pressure on a nerve root can cause inflammation and thereby pain – but their anatomical origin seems pretty certain.

The exhaustive anatomical studies of the Dresden pathologist Schmorl have led to the way to a conclusion of more general biological interest, that the spinal column is the first

organ in man to 'age', that is, to show the deterioration consequent upon ageing.* Pathological changes, it has been said, are detectable as early as the eighteenth year of life. The deterioration of the spinal cord provides, indeed, what is perhaps the best example of a process of ageing which at least *begins* by being a consequence of the cumulative effects of wear and tear – of chronic functional attrition, as opposed to the 'innate deterioration', which takes place independently of abuse, or even use.

Man's upright stance has incomparable advantages, perhaps above all in providing for his principal physical (as opposed to mental) asset, manual dexterity, but it takes its toll in the mechanical vulnerability of the spine. 'Disk lesions' are not, of course, peculiar to man, but it does not derogate from our argument that they should also occur in dogs, for they are found principally in those breeds (bull-dogs, pekinese) which have been deliberately selected for imperfect cartilaginous development. Only we ourselves, therefore, not natural evolution, can be held to blame.

* * * *

The third of man's peculiar shortcomings on our agenda is the appalling ineptitude of wound healing in the skin, and here I shall follow closely the reasoning of Billingham and myself. The following comparison will make the problem clear.

If the entire thickness of the integument in the chest region of an adult rabbit is excised over a rectangular area of 100 cm.^{2}, something that looks superficially like an irreparable injury is produced. But, so far from being irreparable, it requires for its quick and successful healing nothing more than the most elementary surgical care. The surface area of an adult human being is about seven or eight times as great as a rabbit's, but a skin defect of the same absolute size and depth, and the same relative position, cannot by any means be relied upon to heal satisfactorily of its own accord. If left to itself, it will heal painfully slowly, and will gather up and scar; a wound of similar

* It has competitors of course. If we accept the widely held view that the human ovary starts with a fixed number of egg cells, which cannot be added to but are merely used up as life goes on, then the ovary could be said, in a sense, to 'age' from birth. But it is a rather special sense. A clock may work perfectly though its mainspring is uncoiling; it is using up its potential of stored time, but as a timepiece it is as good as fully-wound until it stops.

size in the leg (which is not so much thinner than a rabbit's trunk) could cause a seriously disabling injury if left untreated, whether by gathering up in such a way as to constrict the blood supply of the limb, or by immobilizing a joint. Such an injury cries aloud for skin grafting, an operation in which a thin flat slice of normal skin is removed from some undamaged part of the patient's body and held in place for four or five days over the area of loss. (The skin graft is removed so thinly as to leave behind part of the leathery layer of the skin of the donor area, and the bases of the hair shafts; the donor area will therefore heal of its own accord without scarring or contraction.)

The question is, why is the rabbit so accomplished in wound healing and the human being so strikingly inept; the answer turns upon an understanding of the mechanism of healing as it occurs in a rabbit's skin.

As Billingham and I see it, there are two quite distinct (though concurrent) elements in the healing of rabbits' skin. The first is contracture, which closes the wound by a progressive coming together of its original edges. Contracture follows a regular geometric pattern: starting as a rectangle, the wound first becomes smaller without changing shape; then the sides cave in towards the centre, and meet from the four corners inwards, so that all that is left is a neat shaped line of suture (it does not deserve to be called a scar). During the process of contraction the raw wound area is temporarily covered by a thin film of skin epithelial cells which grow or migrate inwards from the edges of the wound, but as the original skin edges come together so the space enclosed by them diminishes and finally disappears, and the skin epithelium, which is purely a temporary organ of healing, disappears with it.

Contracture closes the wound, but it does not, of course, make good the loss of 100 cm.^{2} of skin. Billingham and I believe that this loss is made good by a second process, the intercalary or 'intussusceptive' growth of the remaining skin. Intercalary growth is an expansion of the skin by growth on or within its existing fibrous framework. The simplest way of demonstrating it is to prepare a rectangular wound and to leave behind, in its centre, a small area of undamaged skin. Alternatively, skin may be excised from the whole of the area and a skin graft thereupon placed in the middle. The forces of contracture which draw the skin edges together bring an expansive force to

bear on the central island, which may accordingly enlarge to no less than ten times its original area. The number of hair roots is not added to,* so that the most obvious outward evidence of intercalary growth is the fact that the hairs growing from the central island become spaced apart to a degree proportional to its linear enlargement. There is nothing particularly novel or mysterious about the intercalary enlargement of skin, for it is a process that occurs naturally in growth from newborn to adult size. It is made particularly obvious by the fact that when a child is grafted with skin, the graft grows with him.

Contracture and intercalary expansion between them make for admirably efficient healing in rabbits. Why do they not work to equally good effect in men?

The answer is probably anatomical. Contracture can only be an efficient healing process if the skin is sufficiently loose to 'give' while it is going on. In rabbits, and in mammals generally, the integument is very loosely knit to the body wall; its main blood supply runs in a plane parallel to the surface, and it contains its own intrinsic musculature (the 'panniculus carnosus') which makes it possible for mammals to twitch their skins. In human beings, the integument is no longer a generously fitting coat, but is much more firmly knit to the tissues below; the intrinsic muscles of the skin are now confined to areas of the face and neck, and the skin generally is much more of a piece with the rest of the body. The upshot of this new anatomical arrangement is that contracture, so far from being an efficient mechanism of wound closure, has become something of a menace; it constricts, disfigures, and distorts, and may yet fail to bring the edges of the wound together. *But it still occurs*: 'human beings may be said to have retained the mechanism of healing by contracture, but to have lost the anatomical prerequisites which enable it to proceed to good effect.' As a mechanism of wound healing, the contracture of human skin is therefore as archaic as the vermiform appendix; like the appendix, we become aware of it only when it leads to harm. Fortunately, thanks to the ingenious and entirely artificial act

* Dr Breedis has recently shown that, contrary to almost all expert belief, the number of hair roots *can* be added to in adult animals, and my colleagues R. E. Billingham and Paul Russell have done experiments which entirely bear out his views. The new formation of hair roots, however, takes place only under certain special circumstances that do not affect experiments of the kind described above.

of skin grafting*, human beings need no longer suffer the dilatory and incompetent ministrations of the 'natural' process of repair. What compensating advantage the human being gets from the novel structure of his skin is far from obvious, though it is hard to believe that there is none.

* * * *

What I have sought to show in this article is that evolutionary advancement is a compromise between which is desirable in the abstract and what can in fact be done; that the lesser evil must be put up with if it makes possible the greater good; and that bad mistakes are made which, though foreseeable to a prescient mind, were not in fact foreseen. The philosophic import of this proposition may well be most debatable, but the truth of the proposition itself can hardly be in doubt.

* More fully dealt with by Professor Burnet in the following article: – ED.

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Strangers Within the Body

Cell and tissue replacement in modern medicine

F. M. Burnet

BLOOD transfusion is probably the most important life-saving measure in present-day medicine – corneal grafting, when it is successful, can make the blind to see. These are the two best known examples of the use of cells or tissues from other persons to make good what has been lost by injury or disease. Many other types of surgical replacement have been attempted in the past forty years, more often unsuccessfully than successfully and the empirical limitations of the methods have come to be relatively well understood. Along with the work of the surgeons in the resuscitation ward or operating theatre, there has been, particularly in recent years, an intensive experimental attack on the principles involved. Together surgical experience and experimental analysis have provided a relatively clear outline of the problems that arise when foreign tissues and cells are placed in the body and the beginnings of a consistent interpretation of the facts.

Blood transfusions were attempted as early as the seventeenth century, but in the light of present knowledge they could not possibly have been anything but futile and dangerous until three technical requirements had been grasped. The blood must be free from any contamination with bacteria, it must be treated so that it will not clot and it must be from a donor of the same species and the same 'blood group.' We are concerned only with the last of these requirements, that the blood transfused will be compatible with that of the patient. Except under special circumstances, it is not very important if there are minor differences between the donor's and the recipient's red cells. It is a different matter when an attempt is made to replace one of the fixed tissues of the body by similar tissues from someone else. In the early days of surgery attempts were made to speed the healing of large raw areas from burns by grafting skin from

another individual. Such grafts never took permanently; at most they might last a week, then the foreign cells died and were thrown off. On the other hand, skin grafts taken from another part of the patient's skin served admirably for the purpose. With proper technique, the grafts 'took' on the raw area and served as centres from which the skin covering could be rapidly renewed.

This provides an outline of the central theme of any discussion on transplantation of tissues. The body accepts its own cells, but 'resents' and casts off those that are foreign to it. There *are* some ways of getting round this principle, but to understand these it is necessary to understand first how the body can distinguish between what is its own material and what is foreign to it – between self and not-self.

The best approach is to consider two of the everyday requirements for the normal functioning of our bodily mechanism. Basically they are very similar. The first is to dispose of worn-out expendable cells like the 1 per cent of red cells that reach the end of their life span each twenty-four hours. The second is to get rid of bacteria or other foreign material that may enter the body tissues either as a result of infectious disease or casually through the digestive tract. In both cases the unwanted material is taken up by a system of cells located in various parts of the body, which it is convenient to speak of as scavenging cells. These cells respond to the two sorts of material in ways appropriate to their differing biological significance.

The bacteria represent potentially harmful invaders and their entry provokes a complex series of reactions that are designed, in the evolutionary sense, both to eliminate the bacteria and to ensure that once the invasion has been overcome there will be a more effective defence against any similar invasion. The central feature of these defence reactions is the production of a specific *antibody* against the bacteria concerned. Antibody is best thought of as a normal protein constituent of the blood which can be produced to any one of an almost unlimited number of *patterns*. The particular pattern adopted has a complementary relation to some aspect of the micro-organism or other foreign material that has stimulated production of the antibody. This is not the place to attempt any description of how antibody protects against subsequent infection. All we need say is that the existence of specific antibody results in an intolerance for the corresponding material. Its re-

entry into the body immediately provokes active responses which rapidly destroy any potentialities for harm.

Worn-out body cells on the other hand are removed and broken down to their constituents without any such complication. The scavenging cells seem to be able to recognize that they 'belong' and that antibody production is not called for. It would in fact be disastrous if antibody against the body's own cells were developed. What might happen in such a case can be seen in the condition now widely known to the general public as Rhesus disease of the newborn. For reasons that we need not elaborate, a mother's blood may differ greatly from that of her child and, in the later stages of pregnancy, it may happen that the mother produces antibody against the child's cells. If this antibody passes from the mother's circulation to that of the child, the infant will be born seriously ill. Within a few days the antibody will lead to massive destruction of its red cells and the resulting anæmia will be fatal, unless it is heroically treated.

It is, therefore, very important that this differentiation between self and not-self should be accurately made by the scavenging cells. If they cannot produce antibodies against invading bacteria the child concerned will die or at best suffer a crippling series of infections, which can only be kept in check by the antibiotic drugs. If, on the other hand, they make antibody against normal cells, anæmia like that in the 'Rh-baby' or other types of serious illness will result.

With such a delicately adjusted mechanism for separating what is self-tissue from foreign material it is obvious that transplantation of any type of tissue from another individual is unlikely to be successful. A certain latitude is available in blood transfusion – cells can differ in minor ways without causing much trouble – but not with tissue like skin or functioning organs. Transplantation of these is sometimes possible, but only when by one way or another we can, as it were, hoodwink the intolerant reaction.

It is quite illuminating to consider the several ways in which nature's demand that the individuality of the body's tissues should be respected, can be overcome.

The first exception to the general rule of intolerance is found when we have to deal with *identical twins*. These are the twins of the same sex, who are always being mistaken one for the other and who, we can be sure, arose from a splitting of a single fertilized egg. All the shuffling and cutting of the two parental

packs of genes and chromosomes had been completed before the egg divided and such twins have precisely the same inheritance. As they developed in the uterus the common stock of genetic material led to the production of cells and complex molecules that were identical in all significant details. If with proper operative technique two small pieces of skin are removed, one from each twin, those two pieces of skin are literally interchangeable. If the piece of skin from twin A is set into the gap in twin B, re-establishment and healing will be as satisfactory as if the twin's own skin had been replaced.

If we are dealing with human beings, an experiment of this sort will only work with identical twins. If it is tried with the commoner variety of non-identical (two-egg) twins who are derived from two distinct ova separately fertilized, the wrong piece of skin will be summarily rejected. But in cattle the conditions are different, and this leads us to our second very important exception.

Dissimilar cattle twins are quite common and they differ from human twins of this type in having as a rule extensive connections between their blood vessels in the uterus. From an early stage, therefore, blood of calf A, with all the cells and substances it may contain, is passing into calf B, and vice versa. When those calf twins are born and raised, they may have quite different markings and even be of different sexes, but reciprocal skin grafting succeeds as readily as if they were identical twins. Investigation of this finding has led to the generalization that if foreign cells and substances are introduced into the embryo they will be integrated into the pattern of the body so effectively that even in adult life those materials will be accepted as if they were the body's own and will not provoke an antibody response. In some distant Brave New World one might conceive that proper injections made into the embryo in the uterus would ensure that when the child reached adult life, he could accept, as his own, transplants of skin or other tissues from perhaps 5 or 10 per cent of people of his own general stock. At the present time such an idea is a mere fantasy with no practical significance whatever.

The third type of exception has been described only in the last year. Very rarely there are born children who through some anomaly of inheritance lack the chemical mechanisms for making antibodies. Even the normal blood protein which is modified to become antibody is lacking, hence the ponderous

name of the condition – agammaglobulinæmia. In the days before antibiotics these children died in infancy. They suffer one infectious illness after another; they cannot develop a resistance of their own, but by free administration of antibiotics and occasional injection of blood protein from normal people they can be maintained in fair health. An American surgeon last year interchanged areas of skin between one such child and an unrelated normal adult. The child who could not produce antibody accepted the foreign skin without reaction. The normal adult showed the usual intolerance for the graft. It is perhaps one of the most direct of all demonstrations that antibody formation is the reason why foreign tissues are rejected.

We can now look at the one practical example of transplantation apart from blood transfusion – corneal grafting. There have been blood banks for a good few years – now we have eye banks, where corneas from persons who have died for reasons not involving the healthiness of their eyes can be stored. The rationale of corneal grafting is simple. The cornea is the transparent front window of the eye. It has no blood vessels and it is free of the wandering cells present in most tissues. If it is damaged or diseased so that its substance is distorted and rendered opaque by invading cells and blood vessels the eye becomes useless. If both are involved the patient is blind. In the operation of corneal grafting the surgeon may be able to remove the opaque area without taking away the whole thickness of the cornea or he may have to make a complete opening. In either case an apprioprately shaped piece of normal and still potentially living cornea must be fitted into the gap. One does not need to stress the delicacy of the operation or the meticulous after-care that is required for success. In highly skilled hands and with patients whose condition is really suitable, success may be obtained in 75 per cent, but there is always a great risk of failure if the patient's condition is long standing and severe.

There is still some uncertainty as to what makes corneal grafting a physiological possibility. The best explanation is probably that we do it in such a way that the body fails to notice what we have done. The clue is the absence of blood vessels in the cornea. If the surgeon can make his new window for the eye fit perfectly and avoid all unnecessary irritation of the other tissues of the eye, he can obtain healing without any extension of blood vessels to the foreign tissue. If this is achieved

the operation is likely to be a lasting success. If, however, there is inflammation at the edge and invasion of blood vessels the antibody response usual for other parts of the body is initiated and the graft is almost certain to become opaque and useless.

So far in speaking particularly of skin and corneal grafting we have been dealing with tissues which to be useful must be alive. There are other forms of tissue transplantation where this is not required. In general this holds when what we need is the strength of non-living elements in such tissues as bone and artery. An artery is made up of living cells, but its main strength is due to the dense mesh of appropriately oriented elastic fibres produced by the living cells, but not themselves alive nor possessing any individuality of their own. If a surgeon replaces a diseased length of artery with a similar length taken, say, from an individual killed in an accident, the elastic fibres are there to do the work of supporting the pressure of the blood. The foreign cells will not be tolerated, but they are usually destroyed and replaced in a slow progressive fashion, which eventually allows the complete replacement of cells by those proper to the patient. Through the whole process the artery has remained a functionally effective unit.

Essentially the same principles hold in regard to bone grafts. Most surgeons probably still prefer to use a piece of the patient's own bone if this is practical, but there are many situations where something else is needed for one reason or another. Bone from another individual, either alive or treated in various ways, may be used to provide a firm framework which will give strength to the limb and be taken over gradually by the body cells whose function it is to mould and maintain bone to its proper uses.

There is one field in which surgical transfers could be of great service if a way around the difficulties of intolerance for foreign cells could be overcome. This is in regard to some of the glands that produce essential hormones. Where the adrenal glands are destroyed by tuberculosis, or the thyroid and parathyroid glands have to be removed for cancer, it would be of tremendous advantage to be able to transplant a healthy gland to replace those removed by disease or surgery. Many such operations have been done, often with temporary benefit. Experimental workers, however, are sceptical of any claims for permanent benefit. In animals, transplants of this type will only persist under very special circumstances.

It seems likely that some of the specialized cells that produce these hormones are identical with similar cells from other individuals of the same species, and theoretically they should be able to survive a transplantation. These cells, however, are always associated with and supported by other cells which have the individuality characteristic of most body cells. When the two sorts are grafted into a foreign host the intolerant response to the second type will usually damage any unindividualized cells so extensively that the whole transplant is rendered nonfunctional. It may be that by weakening the intensity of the intolerant immune reaction we could make it possible for the body to accept the cells that were needed and gently replace those that it could not tolerate by its own. At the present time the drug Cortisone, which damps down many of the immune reactions, is being tested to see whether it can be used for this purpose.

It will be evident that opportunities are by no means so limited as a superficial appreciation of the individuality of body cells would lead us to expect. There will undoubtedly be advances in the next few years at both practical and theoretical levels, but the immediately important task seems to be to push on toward an understanding of the principles concerned. Until those are clear, any new surgical approach is as liable to harm the patient as to benefit him. Basic studies on the individuality of body cells and components have also other important practical justifications, notably in the domain of immunology. And it is hard to overstate their potential importance for theoretical biology. Cell individuality is intimately related to most of the key problems of genetics, embryological development, immunology and protein chemistry.

There is one important finding from practical medicine which bears closely on the capacity of the scavenging cells to recognize and react appropriately against what is foreign to the body although it has nothing to do with tissue transplantation. For the prevention of many infectious diseases we use the injection of appropriate vaccines to stimulate immunity against the corresponding virus or bacterium. As a rule, the killed organisms in the vaccines are so completely distinct from any body component that no trouble arises. Sometimes, however, we have complications closely related to the topics that have been discussed. The classical treatment of rabies (hydrophobia) is to inject a vaccine made from the nervous tissues of rabbits

infected with the virus. In addition to killed or weakened virus, this vaccine also contains nervous tissue from the rabbit. Such tissue is, of course, foreign to the body and antibody may be produced against it as well as against the virus. In a small proportion of those treated by this method, antibody produced against rabbit tissue has a harmful effect on the patient's own nervous tissue and a serious type of paralysis results. The conditions are complex, but experiments in animals have provided a reasonably satisfactory explanation which is too technical to introduce here. The existence of this danger from the injection of vaccines made with nervous tissue was the main reason why no practical vaccine against poliomyelitis could be developed until the virus could be grown in cultures containing no nervous tissue.

It would be quite inappropriate to attempt any discussion here of the theoretical implications of the chemical individuality of cells and tissues. Unless such a discussion went quite deeply into technicalities, it would be unintelligible and useless. All that can be attempted is to mention the sort of thinking that is going on about these problems at the present time. It is becoming evident, for instance, that within an organism each type of cell and tissue has its own degree of chemical individuality and a whole series of chemical relationships to other cells in the body. The ability of the scavenging cells to distinguish between self and foreign material represents only one of these mutual relationships. There is an increasing interest in the possibility that it is in this field of chemical relationships between cells that the anomalies arise which we recognize as cancer. Green of Sheffield has recently put this point of view explicitly, and it is almost as definitely implied in much of the earlier work on experimental cancer.

At a still deeper level we find the problem of individuality in molecules, cells and tissues impinging on one of the newest of theoretical approaches to biology – the application of 'communications theory' to biological phenomena.

When, as in problems of transplantation and immunity, we are dealing with highly complex chemical patterns that interact one with the other in all the varied commerce of the organism, we find ourselves struggling with concepts of a quality that cannot be expressed in the terms of chemistry and physics. It is not that we find any evidence that the known principles of the physical sciences break down at any point. It

is simply that the technical problem of expressing and interpreting the phenomena in chemical concepts and symbols is too difficult now and seems likely to remain so indefinitely in the future. For this reason there is a rapidly developing interest amongst biologists in the general concepts that have arisen from the work of engineers and mathematicians concerned with problems of communication in its widest sense. They deal essentially with the transmission, interpretation and utilization of 'information', a word used in a more restricted sense than in normal English speech.

Once the idea of what communications theory is trying to express has been grasped, it is easy to see that the complex interplay of action in the living cells is not unlike the functioning of a communications system. It seems likely that it may be more enlightening if we regard living activity as a flow of information and instructions than if we cling too firmly to the chemical view that the cell is essentially a bag of ferments breaking down and building up the molecules that forms its substance. No final description of a living organism will ever be possible. All we can seek is a progressively more useful understanding, and the effectiveness of that understanding will be judged by its ability to present clearly the potentialities and limitations of human control over the phenomena concerned.

The individuality of cells and tissues is something very important to medicine, and it is something worth understanding for itself. Its various aspects depend finally on the details of chemical structure that give to the giant molecules of living matter a functionally significant pattern. Those patterns are determined in the last analysis by other patterns, stored in the chromosomes of the fertilized egg cell from which the organism developed. Between the genetic patterns of the chromosomes and the thousands of functioning chemical structures in the cells there must be a multitude of 'chains of command'. If there is a central problem of biology, it is to learn how to express the nature of the process by which these chains of command allow the progressive unfolding of the potentialities of the chromosomes until the adult functioning organism is revealed. The existence of that problem and the means by which we may approach its solution are both implicit in the phenomena that rise from the body's demand that its individuality of chemical structure shall be respected.

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Words, Conceptions and Science*

Michael Polanyi

GUA the chimpanzee was born in captivity on 15th November, 1930, in Cuba, and when she reached the age of seven months and a half she was adopted by Mr and Mrs Kellog, of Bloomington, Indiana, to become a companion to their baby Donald who had just completed the fifth month of his life. During the following nine months the two infants were brought up in exactly the same way and their development recorded by identical tests, which showed a close parallelism in the development of the two. It is true that the child, though the younger, soon took the lead over the chimpanzee and retained this throughout, but the advantage was slight compared with the child's prospective intellectual superiority which was presently to become apparent. For while at the age of fifteen to eighteen months the mental development of the chimpanzee is nearing completion that of the child is only about to start. By responding to people who talk to it, it soon begins to understand speech and to speak itself. By this one single trick in which it surpasses the animal, it acquires the capacity for sustained thought and enters on the whole cultural heritage of its ancestors.

The operational principles of language which account for the entire intellectual superiority of men over the animals seem to be twofold. The first controls the process of *linguistic representation*, the second the *operation* of symbols to assist the process of thought. It is clear that language can assist thought only to the extent to which its symbols can be reproduced, stored up, transported, re-arranged and thus pondered more easily than the things which they denote. Linguistic symbols must be serviceable to this purpose: this is, briefly, the second opera-

* This is an extract from a forthcoming book called *Personal Knowledge*, based on Professor Polanyi's Gifford Lectures of 1951 – 1952.

tional principle of language, which I have called elsewhere the law of manageability. Although both principles are involved in all the developments of articulate thought, I am dealing here primarily with implications of the first principle, and mention the second only parenthetically for systematic completeness.

The first operational principle, which governs the process of linguistic representation, can be recognized as follows. Suppose you wanted to improve a language by increasing its richness indefinitely. We can get an idea of the enormous number of printed or written words that could be formed by different combinations of letters by envisaging the fact that from an alphabet of 23 letters we could construct 8^{23}, i.e. about 50,000 million eight-letter code words. This should allow us to replace each different sentence ever printed in the English language by a different printed word, so that this code word (which would function as a verb) would cover what that sentence asserts. This millionfold enrichment of the English language would *completely destroy* it; not only because nobody could remember so many words, but for the more important reason that they would be meaningless. For the meaning of a word is formed and manifested by its repeated usage and the vast majority of our eight-letter code words would be used only once or, at any rate, too rarely to acquire and express a definite meaning. It follows that a language must be poor enough to allow the same words to be used a sufficient number of times.

It is clear that the poverty of language can fulfil its functions only if our utterances are used consistently. Consistency is an unspecifiable quality. For since the world, like a kaleidoscope, never exactly repeats any previous situation (and indeed, if it did, we would not know it, as we would have no means of telling that time had passed in between), we can achieve consistency only by identifying manifestly different situations in respect to some particular feature, and this requires a series of personal judgements. First, we must decide what variations of our experience are irrelevant to the identification of this recurrent feature, as forming no part of it. Second, we must decide what other variations should be accepted as normal changes in the appearance of this identifiable feature, or should be taken, on the contrary, to discredit this feature altogether as a recurrent element of experience. Thus consistency implies that every time we use a word for denoting something, we perform (and accredit our performance of) an act of generaliz-

ation, and that correspondingly the use of such a word be taken to designate a class to which we attribute a substantial character.

Moreover, by being prepared to speak in our language on future occasions we anticipate its applicability to future experiences, which we expect to be identifiable in terms of the classes accredited by our language. These expectations form a theory of the universe which we keep testing continuously as we go on talking about things. So long as we feel that our language classifies things well we remain satisfied that it is right and we shall continue to accept the theory of the universe implied in our language as true.

The nature of this universal theory which we accept by using a language can be more precisely understood as follows. Of the 2,000–3,000 English words in common usage to-day, each occurs on the average a hundred million times in the daily intercourse of people throughout Britain and the United States. In a library of a million volumes using a vocabulary of 30,000 words the same words will recur on the average more than a million times. A particular vocabulary of nouns, adjectives, verbs and adverbs thus appears to constitute a theory of all subjects that can be talked about, in the sense of postulating that these subjects are all constituted of comparatively few recurrent features, to which the nouns, adjectives, verbs a adverbs refer. Such a theory is somewhat similar to that of chemical compounds. Chemistry alleges that the millions of different compounds are composed of a very much smaller number of persistent and identical chemical elements. Since each element has a name and characteristic symbol attached to it we can write down the composition of any compound in terms of the elements which it contains. This corresponds to writing down a sentence in the words of a certain language.

To talk about things is to apply the theory of the universe implied by our language to the particulars of which we speak. Such talk is therefore continuous with the process by which the theories of the exact sciences are brought to bear on experience. But the connection is still closer with the descriptive sciences. To classify things in terms of features for which we have names, as we do in talking about things, requires the same kind of connoisseurship as the naturalist must have for identifying specimens of plants or animals. So the art of speaking precisely by applying a rich vocabulary exactly resembles the delicate

discrimination practised by the expert taxonomist. Denotation is an art, and whatever we say about things assumes our endorsement of our own skill in the practice of this art.

Last February Donald Kellog turned twenty-four. By now he may have completed his studies at a university and be on his way to become a capable doctor, lawyer or clergyman, destined perhaps to become an authority on medicine, law or theology, or even a pioneer whose greatness will only dawn on generations yet to come – while Gua the chimpanzee, his playmate and intellectual rival until the age of a year and a half, will never have got beyond the stage of intelligence which they both reached as infants. Donald has acquired all his superior knowledge by setting in motion the operational principles of language. This enabled him to profit by an education presented in terms of speech, of print and of other linguistic symbols and possibly even to enlarge this heritage of knowledge by discoveries of his own.

Knowledge acquired by education may be of various kinds. It may be medical knowledge, legal knowledge, etc., or simply the general knowledge of an educated person. We are clearly aware of the extent and special character of our knowledge, even though focally aware of hardly any of its innumerable items. Of these particulars we are aware only in terms of our mastery of the subject of which they form part. This sense of mastery is similar in kind to the inarticulate knowledge of knowing one's way about a complex topography, but its range is enhanced by the aid of verbal and other linguistic pointers, the peculiar manageability of which enables us to keep track of an immense amount of experience, and to rest assured of having access, when required, to many of its countless particulars. Consciousness of our education resides ultimately, therefore, in our conceptual powers, whether applied directly to experience or mediated by a system of linguistic references. Education is latent knowledge of which we are aware in our sense of intellectual power based on this knowledge.

The power of our conceptions lies in identifying new instances of certain things that we know. This function of our conceptual framework is akin to that of our perceptive framework, which enables us to see ever new objects as such, and to that of our appetites, which enables us to recognize ever new things as satisfying to them. It appears likewise akin to the power of practical skills, ever keyed up to meet new situations. We may

comprise this whole set of faculties, our conceptions and skills, our perceptual framework and our drives, in one comprehensive power of anticipation.

Owing to the unceasing kaleidoscopic changes which at every moment manifestly renew the state of things throughout the world, our anticipations must always meet things that are to some extent novel and unprecedented. Thus we find ourselves relying jointly on our anticipations and on our capacity ever to re-adapt these to novel and unprecedented situations. This is true in the exercise of skills, in the shaping of our perception, and even in the satisfaction of appetites; every time our existing framework deals with an event anticipated by it, it has to modify itself to some extent accordingly. And it is most strikingly true of the educated mind; the capacity continually to enrich and enliven its own conceptual framework by assimilating new experience is the mark of an intelligent personality. Thus our sense of possessing intellectual control over a range of things always combines an anticipation of meeting certain things which will be novel in some unspecifiable respects, with a reliance on ourselves to interpret them successfully by appropriately modifying our framework of anticipations.

This is no truism. The oddity of our thoughts in being much deeper than we know and in disclosing their major import unexpectedly to later minds, is a token of their contact with reality. Copernicus anticipated in part the discoveries of Kepler and Newton because the rationality of his system was an intimation of a reality, incompletely revealed to his eyes. Similarly, John Dalton (and long before him the numerous precursors of his atomic theory) beheld and described the dim outline of a reality which modern atomic physics has since disclosed in precisely discernible particulars.

> . . . what the dead had no speech for, when living,
> They can tell you, being dead.

Such major feats demonstrate on a large scale the powers which I have claimed for all our conceptions, of making sense beyond any specifiable expectations, in respect to unprecedented situations.

We entrust the life and guidance of our thoughts to our conceptions, because we believe that their manifest rationality is due to their being in contact with domains of reality of which they have grasped one aspect. This is why the Pygmalion at

work in us when we shape a conception is ever prepared to seek guidance from his own creation; and yet in reliance on his contact with reality is ready to reshape his creation, even while he accepts its guidance. We grant authority over ourselves to the conceptions which we have accepted, because we acknowledge them as intimations – derived from our contact with reality – of an indefinite prospect of novel occasions which we may hope to master by developing these conceptions further, relying on our own judgement in its continued contact with reality.

I have shown that the educated mind relies for most of its knowledge on verbal clues. It follows then that its conceptual framework will be developed mostly by listening or speaking, and that its conceptual decisions will usually entail also a decision to understand or use words in a novel fashion. In any case, every use of language to describe experience in a kaleidoscopic world applies language to a somewhat unprecedented instance of its subject-matter, and thus somewhat modifies both the meaning of language and our conceptual framework. I implied this already when I spoke of denotation as an art.

A re-interpretation of language can take place at a number of different levels. (1) The child learning to speak practises it *receptively*. (2) Poets, scientists or scholars can propose linguistic *innovations*, and teach others to use them. (3) Reinterpretation takes place also at an *intermediate* level in the everyday use of language, which modifies it imperceptibly, without any conscious effort at innovation.

I shall deal with all three of these cases in turn.

(1) The first of the three levels of the re-interpretation of language is that of the child learning to speak. Its early guesswork may appear floundering and foolish to adults, but the conjectural character of linguistic usage which it reveals, is necessarily inherent in all speech and remains inherent in ours to the end. A child will point at the washing fluttering in the wind and call it 'weather', and call the pegs fastening the laundry 'small weather' and the windmill 'big weather'. Such infantile false generalizations in guessing the meaning of words are known as 'childish verbalism', but the mistakes persisting in adult life are quite similar. Few people seem to know, for example, that the common adjective 'arch' means 'cunning' or 'playfully roguish'. Even exceptionally well educated persons may tell you that it means 'oily', 'ingratiating', or 'ironical' or

'pretending to be aristocratic'. We have a comparatively safe knowledge of the most frequently used words, but this assured vocabulary is surrounded in our thoughts by a swarm of half-understood expressions which we hardly ever venture to use at all.

This hesitation reflects a sense of intellectual uneasiness, which induces us to grope for greater clarity and coherence. A child who uses the word 'weather' for rain, clothes pegs and windmills has an unsatisfying and hence unstable conception of weather in which all these disparate things are amalgamated. I can still remember a puzzling conception I had as a child in which buns and luggage were fused together in view of the fact that I could not distinguish between the German words 'Gebäck' and 'Gepäck' which applied to the two respectively. Dylan Thomas tells how he fused in childhood the two meanings of 'front', designating the entrance to the house and the battlefield in France, and wondered at the curious consequences flowing from the hybridization. Rarer words like 'epicene' or 'cynosure' evoke in most of us confused and uncertain conceptions combining disjointed clues, borrowed mostly from the meaning of similarly sounding words. Scholars continue to conjecture about precisely what conceptions are covered by such Greek terms as 'arete' and 'sophrosyne'; their guesses are guided by criteria of fitness similar to those on which the child relies in its fumblings to understand speech.

(2) Confusion may prevail for a long time also in some branch of the natural sciences and be finally resolved only in conjunction with a clarification of terms. The atomic theory of chemistry was established by John Dalton in 1808 and generally accepted almost at once. Yet for about fifty years in which the theory was universally applied its meaning remained obscure. It came as a revelation to scientists when in 1858 Cannizaro distinguished precisely the three closely related conceptions of atomic weight, molecular weight and equivalent weight (weight per valence) which had been used until then in an indeterminately interchangeable manner. The appositeness of Cannizaro's interpretative framework brought new clarity and coherence into our understanding of chemistry.

As another example we may recall how during almost a century after the first appearance of Mesmer, men of science felt that they had either to accept the false claims of 'animal magnetism' or reject all the evidence in its favour as illusory or

fraudulent, until at last Braid resolved the false dilemma by suggesting the new conception of 'hypnotism'. Great pioneers of hypnotism like Elliotson had fallen tragic victims to the confusion prevailing for lack of a conceptual framework in which their discoveries could be separated from specious and untenable admixtures.

Cannizaro and Braid made conceptual discoveries, which they consolidated by an improvement of language; their better understanding of their subject-matter enabled them to speak about it more appositely. Such linguistic innovation is linked in the same way to the shaping of new conceptions as the learning of an established language is linked to the acquiring of current conceptions of its subject-matter. As in the case of childish verbalism, the confusions of which I have given examples in the natural sciences, consisted in a deficiency of intellectual control, which caused uneasiness and was remediable by conceptual and linguistic reform.

When a child confuses homonyms or fuses the meanings of similarly sounding words, or when it is perplexed by verbally formulated problems, to which it has long known the answer in practice, its use of language is obscuring what had previously been clear to its tacit understanding. Such childish sophistication can be cured by teaching children to understand and use speech in accordance with their anterior inarticulate understanding of the subject-matter. Modern analytic philosophy has demonstrated that this may hold also in philosophy. Philosophic problems may sometimes be dissolved by defining the meaning of their terms in accordance with our unsophisticated understanding of their subject-matter.

But purely speculative problems are not always so fruitless. The paradox raised by Einstein as a schoolboy about the behaviour of light in a laboratory moving with the speed of light, was resolved only by his reform of the concept of simultaneity and his conjoint establishment of special relativity. Such clarification of meaning is a discovery, requiring the highest degree of originality.

(3) Language is continuously re-interpreted in its everyday use without the sharp spur of any acute problem, and some kindred questions of nomenclature are usually settled in a similarly smooth fashion in science. The general principle which governs these occasions has already been stated; I shall reassert

it now as follows. In this kaleidoscopic world our anticipatory powers have always to deal with a somewhat unprecedented situation and they can do so in general only by undergoing some measure of adaptation. More particularly: since every occasion on which a word is used is in some degree different from every previous occasion, we should expect that the meaning of a word will be modified in some degree on every such occasion. For example, since no owl is exactly like any other, to say 'This is an owl', a statement which ostensibly says something about the bird in front of us, implies also something new about the term 'owl', that is, about owls in general.

This raises an awkward question. Can we safely sanction the practice of adapting the meaning of words so that what we say shall be true? If we can say of an unprecedented owl, belonging perhaps to a new species: 'This is an owl,' using this designation in an appropriately modified sense, why should we not equally well say of an owl: 'This is a sparrow,' meaning a new kind of sparrow, not known so far by that name? Indeed, why should we ever say one thing rather than another, and not pick our descriptive terms at random? Or alternatively, if our terms are to be defined by conformity to their present applications, would any statement say more than 'this is this', which is clearly useless?

I shall try to answer this by an illustration from the exact sciences. When heavy hydrogen (deuterium) was discovered by Urey in 1932 it was described by him as a new isotope of hydrogen. At a discussion held by the Royal Society in 1934 the discoverer of isotopy, Frederic Soddy, objected to this on the grounds that he had originally defined the isotopes of an element as chemically inseparable from each other, and heavy hydrogen was chemically separable from light hydrogen.* No attention was paid to this protest and instead a new meaning of the term 'isotope' was tacitly accepted. The new meaning allowed heavy hydrogen to be included among the isotopes of hydrogen, in spite of its unprecedented property of being chemically separable from its fellow isotopes. Thus the statement 'There exists an element deuterium which is an isotope of hydrogen' was accepted in a sense which re-defined the term isotope so that this statement, which otherwise would be false, became true. The new conception abandoned a previously accepted criterion of isotopy as superficial and relied instead only on the identity of nuclear charges in isotopes.

* *Proc. Roy. Soc.* (A), 144, 1934, 11–14.

Our identification of deuterium as an isotope of hydrogen thus affirms two things: (1) That there exists in the case of hydrogen and deuterium an instance of a new kind of chemical separability pertaining to two elements of the same nuclear charge; (2) that these elements are to be regarded as isotopes in spite of their separability, merely on the grounds of their equal nuclear charge. The new observations referred to in (1) necessitated the conceptual and linguistic reforms decreed in (2). They rendered the linguistic rule 'all "isotopes" are chemically inseparable' untenable and compelled its replacement by a new usage reflecting the truer conception of isotopy derived from these observations. For to retain the original conception of isotopy, by which the chemical differences between light and heavy hydrogen would be classed with the chemical differences between two elements filling different places of the periodic system, would have been misleading to the point of absurdity. This demonstrates the principle which must guide us when adapting the meaning of words so that what we say shall be true: the corresponding conceptual decisions must be right – their implied allegations true.

So we call a new kind of owl an owl, rather than a sparrow, because the modification of the conception of owls by which we include the bird in question as an instance of 'owls' makes sense, while a modification of our conception of sparrows by which we would include this bird as an instance of 'sparrows' makes nonsense. The former conceptual decision is right and its implications true in the same sense in which the decision to accept deuterium and hydrogen as isotopes, in a modified sense of this term, is right and its implications true. So also in both cases, of owls and isotopes, the alternative decisions are wrong and their implications untrue. There is only this difference between the two cases: the adaptation of the isotope concept to accommodate the observations on deuterium and hydrogen can be specified in terms of an amendment to the definition of isotopy; the adaptations of a morphological concept like that of 'owl' by which it is made to include novel specimens can usually not be so specified.

The adaptation of our conceptions, and of the corresponding use of language to new things that we identify as new variants of known kinds of things, is achieved subsidiarily while our attention is focused on making sense of a situation in front of us. So we do this in the same way in which we keep modifying,

subsidiarily, our interpretation of sensory clues merely by striving for clear and coherent perceptions, or enlarging our skills without focally knowing how, by practising them in ever new situations. The meaning of speech thus keeps changing in the act of groping for words, without our being focally aware of the change, and our gropings invest words in this manner with a fund of unspecifiable connotations. Languages are the product of man's groping for words in the process of making new conceptual decisions, to be conveyed by words.

Different languages are alternative conclusions arrived at by the secular gropings of different groups of people at different periods of history. They sustain alternative conceptual frameworks, interpreting all things that can be talked about in terms of somewhat different allegedly recurrent features. The confident use of the nouns, verbs, adjectives and adverbs, invented and endowed with meaning by a particular sequence of groping generations, expresses their particular theory of the nature of things. In learning to speak every child accepts a culture constructed on the premises of the traditional interpretation of the universe, rooted in the idiom of the group to which it was born, and every intellectual effort of the educated mind will be made within this frame of reference. Man's whole intellectual life would be thrown away should his interpretation framework be wholly false; he is rational only to the extent to which the conceptions to which he is committed are true.

Different vocabularies for the interpretation of things divide men into groups which cannot understand each other's way of seeing things and of acting upon them. For different idioms determine different patterns of possible emotions and actions. If, and only if, we believe in witches may we burn people as witches; if, and only if, we believe in God will we build churches; if we believe in master races we may exterminate Jews and Poles; if in class war we may join the Communist Party; if in guilt, we may feel remorse and punish offenders; if only in guilt-complexes we may apply psycho-analysis instead; and so on. 'Acts follow thoughts,' says the Dhammepada, as the 'wheel follows the hoof of the ox.'

Modern writers have rebelled against the power exercised by words over our thoughts and have expressed this by deprecating words as mere conventions, established for the sake of convenient communication. This is just as misleading as to say e.g. that the theory of relativity is chosen for convenience. We may pro-

perly ascribe convenience only to a minor advantage in the pursuit of a major purpose. It is nonsense, for example, to compare the convenience of interpreting sudden death in the idiom of witchcraft with the convenience of using instead a medical terminology; or to compare the convenience of describing political opponents as such, with that of calling them spies, monsters, enemies of the people, etc. Our choice of language is a matter of truth or error, of right or wrong – of life or death.

The understatement that language is a set of convenient symbols used according to the conventional rules of a 'language game' originates in the tradition of nominalism which teaches that general terms are merely names designating certain collections of objects – a doctrine which, in spite of the difficulties admittedly attached to it, is accepted to-day by most writers in England and America, in abhorrence of its metaphysical alternatives, like essences and Platonic ideas. The question how the same term can apply to a series of indeterminately variable particulars is avoided by admitting that terms may have an 'open texture'.* Such open terms, however, lack any definite meaning; so the nominalist has either to refrain from enquiring how they can be applied, except arbitrarily, to experience; or, alternatively, to invoke a set of vague regulative principles – without asking on what authority these rules are to be accepted and how themselves applied, unless arbitrarily, in view of their own vagueness. All these deficiencies are overlooked in an overriding desire to avoid reference to metaphysical notions or at least to cover these up under a cloak of nominalist respectability.

I suggest that we should be more frank in facing our situation and acknowledge our faculty for recognizing real entities, the designations of which form a rational vocabulary.

* See F. Waismann, 'Verifiability', in Flew, *Logic and Language*, I, Oxford, 1952, p. 117 ff.

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The Contact of Cultures

F. C. Bartlett

1. *The Setting for Contemporary Culture Contact*

IN every country of the world, and from many different points of view, people of reflective mind are now, more than ever before, being forced to think about the consequences which inevitably follow when differently organized social groups enter into effective working relationships. The phrase 'contact of cultures' has acquired a new significance. No longer can we be content to consider only, or chiefly, how small, distant and primitive communities influence one another when they come into close association, or how they may be affected by the encroachments of some larger and more powerful civilization. Many problems of this order still remain, and doubtless many more will develop. But the contacts that it has become most of all urgent and vital for men to understand are between those very large social groups which are the representative groups of the modern world.

There are many reasons to account for the fact that our understanding of the mechanism and results of the contact of contemporary social groups is meagre, and for the most part speculative only. Three of these are of predominant importance.

The first is that the present instruments and media of mass communication are mainly technological and have become established with startling rapidity within a very short space of time. The second is that the contacts which nowadays we have to try to appreciate are between exceedingly large social groups, and it is not yet sufficiently realized that the determination of human behaviour within the very large social group may be radically different from that operating in the smaller and more primitive societies with which those people who have studied the associations of different cultures in the past have been principally concerned. The third outstanding reason for lack of accurate knowledge about the effects of the

contact of social groups in the modern world is partially consequent upon the first two. It is that so far nobody has developed adequate experimental methods for their study. It may well be the case that the nature of the problem is such that no completely experimental technique ever can be developed. The numbers of persons involved are very great and it is at least a reasonable hypothesis that some of the effects of contact are directly dependent upon characteristics of social organization which are not found except in extremely large groups. Certainly a great part of the discussion in this article will be on a level of generality in which the appeal is bound to be rational rather than experimental. Nevertheless, there are many aspects of the problem of cultural contact which seem as if they should be perfectly amenable to controlled investigation. I will indicate some of these, though they cannot be pursued in detail here. It is certainly my view that unless every chance is taken to develop and exploit experimental approaches an unhappy dogmatism will continue to dominate this as well as every other branch of social psychology.

The growth of the influence of technology in social life and the increase in size of the effective social group in the modern world are closely associated. They are, in fact, different aspects of a single general social process. I am going to assume that it is better to begin with a consideration of the technological character and instrumentation of modern culture contacts and of their outstanding results, and it is with suggestions about this kind of study that the present discussion is concerned.

2. *Old and New Forms of Social Contact*

Several years ago I was a visitor to a group of natives in what was at that time, from the point of view of the settler from a different civilization, an isolated region of South Africa. One day, certain of the leading members of this small nation group collected together all the available oldest people of the community, and some of the youngest, and I was invited to watch them re-enact some of their ancient, fast disappearing, or perhaps already obsolete, cultural practices. It was an occasion on which the traditional and the novel were mingled, though I do not think that we were very much aware of anything incongruous at the time. The natives sat on skins, or robes, or on the bare ground in their established order of precedence; but a Euro-

pean-made armchair was produced for my greater comfort. Native beer was handed round in cermonial fashion, regalia and clothes, now little or never seen in public, were donned and their functions demonstrated; children danced and played games as the children of this group had done for unnumbered years. We watched the ancient fire-drill, which none of the young could perform, and everybody got very excited when we saw the first glow and the spiral of smoke, and soon the fire was leaping into flame. I had never seen this before and I think some of the natives had not either. At any rate, I find, looking at the record which I wrote at the time, that when the fire broke out there was excited and spontaneous cheering. We talked long about old ways of life, some of which still persisted, though not openly. Then, as the day wore on, my turn came. I had to try and describe something of English life and practice. I handed round photographs, which were greatly admired, but apparently extremely hard to perceive with any understanding.

In the evening of that day, when I returned to my settler headquarters, I found that my hosts had arranged a special cinema entertainment. There was an American film. I have forgotten most of the details except that it was what would be called very 'pretty' and sentimental and about as far removed from the immediate African scene as it possibly could be. This was followed by an old film of the May races on the River Cam, in England, which somehow or another had been brought in for my particular pleasure. It was a day of astonishing contrasts, and I particularly recall how, as I looked back from the screen, there, in the reflected light, I could see, peering in from every possible standing place, the intent, dark faces of African natives. In the morning I had joined in some of their culture. At night they were participating in some of ours.

Here was a contact of cultures, and one moreover in which the old and the new were curiously combined. The old ways, studied for many years, and often to great purpose, by anthropologists, always required some form of personal association.* By immigration, temporary or permanent, the borrower went out from his own social group, picking up this or that item from his host group, and sometimes returned with his spoils to begin new social movements among his own people. Or, by migra-

* See, for example, 'The Contact of Peoples', W. H. R. Rivers, in *Psychology and Ethnology*, London, 1926, 299–317.

tion, whole societies moved, taking their material and psychological possessions with them and, coming to rest, by conquest or infiltration they set up elaborate processes of give and take between differing whole groups of culture. The old ways have never vanished. In some respects they exercise influences more actively now than ever before. In particular, modern freedom, ease, cheapness and speed of travel have enormously facilitated that process of temporary immigration which is more often a source of the borrowing of details than of any genuine blending of large blocks or systems or culture. But the new ways have become predominant. Alien cultures and items of culture travel impersonally to people, even more often and even more effectively, than people travel to alien cultures. The older manner of the contact of persons is now so profoundly affected by the newer manner of the contact of possessions that the primary problem is to understand how the latter works and what it can do.

3. *New Forms of Culture Contact*

All the distinctively modern forms of culture contact depend directly upon the development and use of that kind of symbol which can be given a permanent and objective expression. Whole cultures, or items of culture, are represented in pictures and diagrams, in words, codes, numbers, especially in numbers that can be thrown into a statistical form.

Not only so, but the symbols are essentially detachable. They achieve a character and expression by virtue of which they can go about by themselves, so to speak, be ordered, reproduced, and in some manner understood, by people who had nothing whatever to do with their origination. They can also be so restructured in any receptor group that, though they retain their descriptive character, they acquire totally different functions.

Symbols which can be so detached seem as if they ought to be able to present that for which they stand in a kind of dispassionate manner. Paradoxically, in their most common forms of expression they have come to possess a speed, an urgency, a liveliness and a quality of decisive definition unknown to the older ways. Within a very few generations man has seen a growing dominance, for culture contact, of the book, the mailed letter, the daily newspaper, the cable and the telegram; of the cinema, the telephone, the radio and television and now radar devices in great variety. The effective range, the continuity of

operation, and the speed of transmission in the case of all of these have increased rapidly. Now a similar range, continuity and speed have invaded the field of personal contacts itself. People rush from country to country for weekends, every moment of which seems to be clamorous with opportunity. It seems a lot easier than it once was to 'take time by the forelock'.

Behind every development of these new forms of contact there stands some triumph of applied science, and together with that, more often than not, first a process of mechanization and large-scale production, and now a rapidly spreading process of machine automatization.

Some of the characteristic forms of a group's possessions may still be the product of the inventiveness of single persons who can be identified. More frequently they are the combined results of the work of a large number of people often joined together into organized teams. Before characteristic possessions reach an expression in which they can travel they are, almost always, already largely standardized. This means that the processes of modification which may follow their movement into new societies requires much more premliinary interpretation on the part of receptor groups. If they are accepted and 'tried out' it is usually only after a lot of preliminary discussion.

For example, any visitor to Africa a few years ago must have been impressed by various items of house architecture, copied from more highly industrialized, or 'civilized', groups, and introduced into the native hut – small crosses set up, now in one position and now in another; rudimentary chimneys; doorways after the European or American style. They were the results of direct experiment, often varying greatly from one instance to another, and reaching their adopted form by a process of trial in practice. When architectural changes spread from one large group to another, they usually illustrate a different mechanism of transfer. As a rule, the proposed innovations are first represented in some relatively final and complete symbolism, in models, pictures, diagrams, or by detailed description. These are the agreed forms in which some group of experts from the innovating culture set them travelling. In these forms they must then be appraised by an 'audience', and more often than not by another set of acknowledged experts in the receptive group. The degree and manner in which they are to get into receptor culture are more or less decided before actual trial is made.

Consider a remarkably interesting recent discovery of a

mnemonic pictograph system developed and used by an Iroquois chief to assist him to play his part correctly in an elaborate native ceremonial in which he must use personal names in correct order of precedence and with extreme exactitude.* American Indian pictographs in general possess many characteristics which have been borrowed from the use of representative symbols in groups other than their own. The pictographs constituting this particular mnemonic, in their form, in their function, and in the way in which they were recorded are an outstanding example of 'borrowing transfer'. In their form they exactly resembled somewhat conventionalized white man's drawings of human heads and faces; their function was precisely that of aiding ordered recall for which such drawings are often used in the groups of their origin; they were recorded in a small American 'exercise' or notebook. They remained in this instance personal to the chief who used them and were experimentally developed by him, through a series of trials, into the forms and groupings which he found most effective.

There are many instances in every large and highly developed modern society of a similar transfer of language forms, of special diagrammatic devices (such, for example, as the widely spread pictorial types of statistical display) and of systems for aiding memory. Sometimes they are taken up by individuals, much as the Iroquois chief adopted and developed his pictographs, are shaped experimentally by them, and then, if they continue to spread, they do so by an expanding series of personal contacts and a process of individual trial and error. This is not now the characteristic method in the large social group, however. It is much more likely that the items which, so to speak, are appropriate for transfer, will be given some kind of initial publicity, usually already in a fairly complete and systematic form, and presented as desirable either to groups of experts or to a general population. They can be seen in public advertisement, on the cinema, through television and in organized exhibitions of one kind and another. They can be heard on the gramophone and the radio. They can be read in the ordinary news columns of the popular press. They have first, that is to say, to make an appeal to some kind of an audience, and only then, usually with

* 'Some Mnemonic Pictographs relating to Iroquois Condolence Council', by J. B. N. Hewitt and William N. Fenton, *Journal of Washington Academy of Sciences*, vol. 35, No. 10.

considerable detail already determined, will they be assimilated or rejected by the culture to which they have come.

The more specialized the items of transfer the more marked and important this process of evaluation by, or exhibition to, some kind of an audience has become. Let us consider a few actual and recent instances. One of the curious things about current industrial organization is the different degree to which comparable industrial groups in the large national communities of the world have become mechanized. There is, however, a tremendous push to increase mechanization in almost all the large working groups of every industrialized society, and sometimes, for a variety of special reasons, this push suddenly becomes intensified. Such a condition was reached a few years back by the coalmining industry in Great Britain. Under modern circumstances, whenever this happens certain members of the society which is oriented towards increased mechanization at once begin to look abroad, outside their own group, for instruments or suggestions for instruments. Specific contact of different cultures is strongly stimulated. But there is now little need for the innovators to organize migrating groups or even to send out migrating individuals. They can get catalogues, drawings, descriptions, and under ordinary circumstances relative freedom of trade and ease of transport make it possible to obtain actual machines which are alleged to have been used successfully in alien groups. Machines are therefore acquired or are constructed according to pattern. Approved by the expert, they are put rapidly to work, and either at the same time or soon afterwards a public exhibition is usually organized in which the machines can be seen in operation, as a rule under extremely favourable conditions, and popular support for them is sought. Such a course of events marked the beginnings of the projected rapid expansion of mechanization in coalmining in Britain; and it has become a regularized procedure all over the world for the utilization of the technological developments of one culture group in the technological practices of groups of differing culture.

4. *The Experts and the Audience*

Broadly speaking, the regular sequence of events in the field of technological culture seem to be something like this. If any marked technological development takes place in any of the large groups of the world which promises or begins to achieve

enhanced economic prosperity, all the other large groups very soon begin to yield to a pressure – that is, partly economic and partly a matter of pride of technological prestige – to receive the new development into their own culture. First, sets of experts will take the descriptions or designs of alien experts and evaluate them, perhaps beginning to try to put them into whatever form they consider to be most in line with the established technology of their own group. But then what the experts have achieved must be submitted to the wider audience of everyday practitioners, and this is done by all sorts of recognized publicity methods.

It is just at this point, as it seems to me, that there is a very great need for more controlled studies and a very great chance to make them. Nobody knows with any certainty what the publicity methods which have been developed in all the great social groups as a main medium of culture contact can do and what they cannot do. There are, it is true, a few studies of what an audience is likely to do with material which has been specially prepared for its assimilation. But at the moment many more are needed, and with special concern for technological spread.*

I think there are special reasons why every large group should be particularly interested in discovering all that can be found out about how technological culture contact normally proceeds and what means can make it most effective. These are connected with the imminent invasion of very large tracts of everyday activity in the social group by those devices which are programmed for various forms of self-control.

It seems certain that every large and relatively independent social group will have to accept and operate all the applied scientific developments that are associated with what American writers have decided to call 'automation'. It is also certain that this will carry with it many consequences in the way of social organization and practice which are not, in any strict sense, confined to material technology. Every large group will have to develop or acquire a skilled population. But this demands wide popular recognition of the need for knowledge about the nature

* N. G. Hanawell and K. F. Rutlinger have shown in detail what some of the effects of presentation to an audience may be in their article on 'The Effect of an Audience on Remembering', *Jour. Soc. Psych.*, 1944, pp. 259–72. They include a bibliography. Further relevant studies have been made by Mrs E. Belbin, Medical Research Council, Applied Psychology Unit Report, No. A.P.V. 121/49.

and conditions of human skills and how these can effectively be trained. Moreover, it appears probable that in every special group a 'skilled' population will mean that traditional and long-established practices that are regarded as demanding great skill and responsibility will have to yield pride of place to forms of skill that have a far shorter history behind them. Also a skilled population will almost certainly be a relatively leisured population, and it therefore seems probable that a spread everywhere of automatized working devices will, if it is not to raise far more problems than it solves, have to carry with it consequent culture changes in education and general intellectual outlook which do not belong to the material side of culture at all, and are, on the whole, very much more difficult to direct and control without strife or turmoil.

5. *The Spread of Ideas*

It could at least plausibly be maintained that a survey of contemporary technological practices would suggest that all the big social groups are rapidly becoming more alike, and that the probable next move towards increased use in industry of automatic self-regulating devices will make for even greater uniformity. Yet these big groups still remain distinct and, in many ways besides the geographical, genuinely separated one from another. Indeed, it is difficult to avoid the impression that in certain respects group hostilities are, or are potentially, sharper and more stubborn than ever.

It has for a long time been customary to distinguish between two processes in the movement of culture. A group may accept details from another group and assimilate them to its own setting. Or, again, two or more cultures may combine and produce something which is neither the one nor the other but a true blend of both, or all. The second usually takes far longer than the first, for it demands two or more assimilation processes, not only one. Unfortunately terminology is very shifting and unsettled in this topic of study, but perhaps it is best to call the first process 'borrowing', and the second 'blending'; and at any rate that is the sense in which these terms will be used here. Then it is clear that there may be borrowing with little or no blending, though very likely there can be no blending without a considerable amount of borrowing.

All the considerations put forward here indicate that the contemporary social scene is extremely favourable to borrowing.

For the general condition of this is that items should be readily capable of being detached from the setting in which they have grown up and assimilated to another one. This is what can more and more easily happen as symbolisms are developed which become more and more capable of representing the items adequately, and at the same time more and more accessible to human intelligence independently of geographical and other local conditions. Moreover, intelligence itself is, as many people have pointed out, predominantly analytical and better adapted to assess and value detail than to be impressed by massive and somewhat undifferentiated settings.

It is indeed possible that social conditions which are highly favourable to borrowing carry with them something that is antagonistic to blending. But whether this is the case or not – and it certainly ought to be possible to get a definite experimental answer – it is certain that great technological similarity is consistent with equally great ideological difference.

So far it seems as if the only really effective way discovered by man for producing a lasting blend of culture is the method of more or less mass migration. For it appears to be necessary that details should be carried within their historically determined settings and should come into persistent and first-hand contact with other settings complete also with their own traditional detail. But once social groups become very big this is exceedingly difficult, except in so far as mass movements within the limits of a particular large group are concerned. If the only way by which a genuine blending of cultures, as distinct from a borrowing of technological practices, can spread is by large-scale migration and resettlement, it would seem as if the outlook for the world is none too good. For blending then becomes an end-result of long processes of troublesome and risky adaptation which has always in the past had to survive periods of open and often violent hostility.

At the present time nobody can claim to know how a large scale blending of cultures can be achieved; but to recognize the lie of the problems, and that they can be studied by scientifically directed methods, are the first necessary steps towards understanding.

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That Thing from Another World

Peter Fison

THE trouble is that Science-Fiction is taking itself too seriously again. The Pulp magazines carry topological articles. The *Observer* claims it for Christmas competitions. Old magazine stories are suddenly appearing between hard covers and a Science-Fiction novel heads the Gollancz autumn list. Soviet scientists announce the solar system to be waiting breathlessly for the Marxist Columbuses, and Edmund Crispin prefaces a collection of Science-Fiction shorts with a critical apologia of the sort Dorothy Sayers forced on the detective story in the twenties.

Science-Fiction (Sf. in the jargon) is become the most classical of contemporary forms. The strip cartoon apart, it has long denigrated any association with the real world of lusty blonds and handsome rocket pilots. Instead a number of narrow categories are imposed, within which ever more suble variations must be rung on a limited selection of themes according to predestined rules.

There is time travel and the old favourite of first-year philosophy students about travelling back into the past and murdering your own great-grandfather before he had committed any descendants. There are the visits to and visitors from alien worlds and the various means of reaching understanding or massacre. There are Robots, obviously superior in every way to Humans, and how to keep them in their place. (Catastrophes like *R U R* are much too crude for contemporary writers. They prefer situations like that in *Final Command*, where the earth has been for centuries at war with an alien star system. The first alien eventually captured greets his human interrogators with immense enthusiasm, for, having met only Robot armies, his race had never realized that there was a non-mechanical life-form behind them with whom it might be possible to make peace.)

There are, bless 'em, the Mutants. They provide the necessary villains. It is considered tendentious in Science-Fiction to brand any race with a criminal representative. Like school stories, exploration rockets have always a Negro or a Chinaman aboard and, amongst the more daring, occasionally even a Slav. But who can be accused of chauvinism against mutants? Particularly when they are of another species, like the rats – all ships have rats – who are exposed by an accident in space to cosmic radiations. A mutated strain develops and with their high reproduction rate the rats are soon able to take over the spaceship, whose crew dare not land their monstrous cargo on Earth. Or the even more pleasing fancy in *Big Ancestor* of the human race as the descendants of cosmic vermin from one particular shipload of supermen.

Satellites circling the earth or the potentialities of transuranic elements are left severely to the three-halfpenny newspapers. An interest in immediate techniques went out with Jules Verne; predictions are too rapidly overhauled by facts. It took a quarter of a century for air forces to catch up with Wells's *War in the Air*, only eight years for a case to be brought in the U S courts analogous to the *Astounding* Science-Fiction Magazine story of rain 'stolen' from droughty farmlands to feed a pleasure resort. And the editor of another magazine got into trouble in 1944 for anticipating the atomic bomb in fiction.

Not surprisingly, therefore, Sf. writers prefer the distant future. But even here fantasy is kept tightly in check. Intergalactic relations are difficult, as the mere journeys between clusters would take several lifetimes at the speed of light. To facilitate this, Sf. authors postulate 'Hyper-space', in which, despite the organization of the universe, speeds many times that of light are possible. Fantasy at last? *Astounding* carried a series of articles examining the physics of hyper-space in terms of Cantorian mathematics and Tarski's paradoxes. Mathematically, hyper-space now exists and there remains only the minor problem of engineering with non-denumerables. And then Westward Ho for Betelgeuse.

The more cautious Sf. writers deviate into parapsychology, though only of the most orthodox kind. Theodore Sturgeon's *More than Human*, which headed the Gollancz Fiction List last year, postulated '*Homo Gestalt*' as the next quirk of evolution: a hero who is in fact only a fragment of an intuitive complex of six people, each of whom has a particular parapsychological

faculty – clairvoyance, psychokinesis, calculating ability, teleportation, etc. – but who are (is? Grammar baulks) only a personality when acting together.

This was presented as a serious novel, which indeed it is; a Wyndham Lewis harshness in the portrait of a tormented childhood trying to realize itself, though the early part runs a bit too much on flagellation, with a two-page extract from *Venus in Furs* thrown in for good measure.

His fierce morbidity is more effective in the parables Sturgeon passes as short stories, like *Farewell to Eden*, where an idyllic couple of 'blue creatures' from a distant planet lands on earth and is torn to pieces by the degenerate humans. A man and a woman, disgusted by this, determine to leave earth. They land on an unknown planet . . . and are torn to pieces by degenerate blue creatures.

Not all Sf. stories are unpleasant, but the majority of those concerned with the future have a sombre tinge. The world of *1984* was familiar to the Science-Fiction reader long before Orwell. Utopias, when they are not slave-labour camps, are usually sterile. Perfection is agoraphobic, as in Arthur C. Clarke's *Towards the Fall of Night* or Lester del Rey's *The Years Draw Nigh*. Here mankind, though potentially immortal, has abandoned ambition and yields gladly to extinction. Men have spread across the solar system and found it empty except for the relic of a civilization on Mars, all life long extinguished. Obsessed by loneliness, further safaris trek the universe and find no other inhabited planets: only one ship limps back, centuries after the rest, having found on the farthest periphery ruins identical with those of Mars, all life long extinguished.

After this Sprague de Camp's *Ordeal of Professor Klein* comes as a relief. He thinks to have discovered a Rosetta Stone to decipher the language of 61 Cygny A VI and 'The lost epics of the Hrata Empire' only to find an advertisement urging him to 'Use Prvny's excellent soap'.

Such an approach is rare, however. Looking into the future, Sf. writers see death and decay in all around them. Even Robots, used up and sent for scrap, develop a death ritual or linger in a world devoid of man, succumbing one by one to *Rust*. The annexation of other planets moves Ray Bradbury to a fine disgust, while spacemen, their service over, pitch hot-dog stands amongst the Martian ruins. A great proportion of these stories are eschatological. With the hydrogen bomb grinning

over their shoulder, it would seem Sf. writers have little need to go further afield for desolate planets and clocks ticking emptily in a dead world. But they prefer to exercise their ingenuity on situations like Philip Latham's *The XI Effect*, one of the few purely 'scientific' shockers. This postulates a local shrinkage in the space-time warp of our cosmos. At first no difference would be noticeable, for everything contracting at the same rate would still be relatively the same. Eventually, however, certain constants, like the length of light waves, would be surpassed. First red, then the other colours of the spectrum, would die out while the world, in silent panic, waits for an end the author cannot quite conceive.

Even when the future doesn't come to a sudden stop, it is seldom pleasant. The nastier present-day trends are extrapolated and taken for granted. Psychologists run the world governments and, for their own good of course, try to keep men from the stars. Mankind is usually a mob, undistinguished and unindividualized, behaving on the lowest common denominator. There is the insubordination, the exaltation of the personal grudge so familiar from transatlantic war films. Power is in the hands of blustering senators, who apply the ethics of the corn belt to the planets; politics are the playgrounds of huge corporations, and capitalism or state totalitarianism, both on a tremendous scale, organize the solar system. Cultural progress is limited to 'Symphonies of Smells,' the unified field theory, or a concerto casually dashed off by a child Mutant aged four; philosophy is advertising and scientists are kept on a leash by the military. This is given an ironic twist in Edward Peattie's *The Conners*, where a physicist escapes from his station into a post-atomic-war world only to realize that his 'guards' were designed to protect him from the frenzy of the anti-scientific mobs.

Though the spread of the more unattractive aspects of our culture is taken for granted, it is not necessarily approved. At the end of the story the rebels succeed, or if they fail their failure is tragic. Many Sf. authors seem to be working out the contemporary American fashion for guilt about the imperialist rôle thrust upon her. In general there is a dislike of cities, a longing to return to the 'quiet little home town' world of the turn of the century. The same is, I believe, true of Soviet Science-Fiction. Though hardly a conscious attitude, it keeps breaking through.

Most of these young writers are academics and liberals. Van Vogt is a physicist, Azimov a biologist, Clarke an astronomer,

and Sprague de Camp a dedicated debunker of historical myths. Others are mathematicians, scientific publicists or dons. In recent years it has been inadvisable for such people to assert their radicalism except as fantasy; a purpose historic in the genre from Plato's myths, through the *Utopia* and *Back to Methuselah* to *1984*, intended by Orwell primarily as a swaddling for 'New-Speak'. To-day C. S. Lewis still uses the form overtly with the same intention.

It is an elementary Sf. creed that Atlantis, fifteen millennia ago, dabbled in atoms and paid the consequences. Of course, any man with imagination is worried about the future, and scientists particularly can sense trends and have too often seen their predictions realized. Cobalt bombs and psychological warfare are sufficient reason for the transmutation of Wells's optimism (and there is always *Mind at the End of its Tether*) to the dark presentiments of to-day.

English writers are perhaps a little less gloomy that their American counterparts. It is difficult to judge, for most of them are still young and grew up with *Astounding*, which so influenced their style that it is not easy to distinguish them.

There seems, however, to be a slightly more individual approach. American writers paint Humanity's reaction to the frequent Apocalypse in the muddiest colours. Few, the particular heroes apart, behave well. Animal stoicism or mass panic are the rule. Perhaps in Europe we have had greater experience of the human spirit under bombardment, or perhaps the background merely seems more authentic to us than American scenes. Certainly John Wyndham's *Day of the Triffids* builds up a more convincing picture of calamity, with the whole world struck with blindness and carnivorous plants on the lour. Some people behave well, others badly, most merely foolishly. But at least they do so with the variety of real human reactions and not like a flock of sheep. Characters are individually etched, down to the night-club hostess so conditioned by earlier disasters that 'she had an utterly unshakable conviction that nothing serious could have happened to America and that it was only a question of holding out for a while until the Americans arrived to put everything in order. . . .' Arthur C. Clarke, another Englishman, has the same touch for the absurdly likely in *Childhood's End*. The world is invaded by alien 'Guardians', who establish a world government and put everything to rights. When they abolish bull-fighting in Spain, 'The London *Daily Mirror* made

matters much worse by suggesting the Spaniards adopt cricket as a new national sport'.

In America this ability to project contemporary reactions convincingly is more limited to the immediate future. Robert A. Heinlein has a rigidly planned history of the next few hundred years against which he sets his stories. From there he goes on to planetary conquest, a Botany Bay colonialism on Venus, revolt of the under-privileged in a new evangelical revival, and stasis in a theocratic dictatorship. The danger of this approach is its liability to be overtaken by events. Recent American announcements have already outdated Heinlein's *The Man who Sold the Moon*, a study in high-pressure salesmanship. D. D. Harriman is just short of being a crook, a brilliant financier with the distant imagination common to so many tycoons. In his case this is the moon. By selling advertising space on it, starting missionary societies, children's moon clubs (with badges) and every other device known to the publicist, he eventually raises enough money to build a rocket. In *Requiem*, himself an old man and now physically beyond space-travel, Harriman tries illegally to visit the moon, to which he has sent others without ever finding time to go himself, in order to die there.

In *It's Great to be Back* a couple returning to earth from the air-conditioned artificiality of Luna City find it impossible to settle down again on a world that seems to them germ-ridden and filthy. *Logic of Empire* is a study of indentured labour on Venus that reads like *Uncle Tom's Cabin*. In *The Green Hills of Earth* a blind ex-pilot travels the space-ways as a vagabond, composing the minstrelsy of the rockets. The doggerel lines quoted hardly support the Homeric analogy, but the idea is pleasing.

Fritz Leiber in a rather different way also pursues naturalism. In *The Ship Sails at Midnight* the visitor from another world appears in a small American university town. The clique of élite academics in the cheap cafés discussing pointlessly far into the night seems genuine, a mid-western correlative to the provinces of Snow's *Time of Hope*; and the tragic ending, when the visitor falls in love with one of them, is more sensitive than such things usually are.

Sprague de Camp is equally refreshing in his *Viegas Interplanetarias* sequence, where world culture for once is not English but Portuguese. A sense of humour like de Camp's is rare, though the versatile Lewis Pagett comes near to it in *Robots*

Have no Tails. These are stories of young Gallagher, a scientist with two personalities: his own demure self and Gallagher Plus, who takes over when he is drunk. When ordinary Gallagher wakes again, sober, he is confronted by weird and meaningless constructions, the genius Gallagher's solution of exotic problems of whose very nature he is now ignorant. Life is further complicated by the Lyblas, harmless creatures from Mars, rather like rabbits, who after a steady diet of comic strips want to conquer the world, 'Kidnapping pretty girls and destroying cities' they assure him in a squeaky voice while he feeds them with sweets; and by Joe, a narcissistic Robot too busy admiring the perfection of his own interior mechanisms to be of any use to anyone else.

In order to present the future convincingly, however, it is not sufficient to postulate contemporary behaviour. New conditions will bring new culture patterns, and these are usually ignored by Sf. authors. Judith Merril occasionally plays with matriarchy. E. C. Tubb's *Starship*, which pushes towards Andromeda for three hundred years while the generations die and repeat themselves aboard, demands an ethic that by duelling, intrigue and treason disposes of as many lives as possible that there may be room for renewed life. Abernathy's *Pyramid* presents a world where the moral impulse of every species is geared to the preservation of a balanced ecology, and in James Blish's *A Case of Conscience* a Jesuit evaluates the dangers of a planet without original sin.

Like a clairvoyant Toynbee, Isac Azimov prefers to trace grandiose designs of the rise and fall of cultures on the galactic scale. For once one feels these planets and their social systems are real. He has John Buchan's talent for making us feel at home amongst the great. His war lords and scheming ambassadors in *Currents of Space* – one of the few good full-length novels – really convince. In the series of books called *Foundation* he sketches the break-up of the first great Galactic Empire, through anarchy and feudalism, theocracy, corruption and rip-roaring trader capitalism back to an attempt at civilization. For a thousand years his heroes stalk the ruins of the future through the Periphery, past huge planets now deserted, empty Babylons where the Barbarians feast. In *Nightfall* there is a world with six suns that has never known complete darkness and whose inhabitants go mad when the stars appear.

Azimov sometimes entangles his ideas in the mere me-

chanics of writing, and this is a fault common to many of the best Science-Fiction authors. With a very few exceptions their novels are likely to be a loose series of related episodes. Characterization is perfunctory and usually comes in three brands: good, bad, and neurotic. The style is frequently turgid.

The exception is Ray Bradbury, whose great lay reputation is due chiefly to his papilionaceous prose. It has a jewelled lyrical quality, a tenderness like that of Truman Capote and some of the younger Southern writers, and he can linger nostalgically over a sentence. His themes are not particularly original and depend too often on the application of earth concepts to extra-terrestrial situations. The women who in *The Wilderness* are preparing to join their husbands in colonizing the planets are really just the wives of pioneers on earth waiting to depart for strange continents.

Bradbury is particularly sensitive to the obscenities of our civilization imposed on other cultures, and occasionally, particularly in his early *Martian Chronicles*, this leads to a wider sympathy. The Negroes in *Way in the Middle of the Air*, for instance, who decide to abandon Dixie and seek a freer life in the sky:

> The black warm waters descended and engulfed the town. Between the blazing white banks of the Town stores, among the tree silences, a black tide flowed. Like a kind of summer molasses it poured turgidly forth upon the cinnamon dusty road. And it surged slow, slow, and it was men and women, and horses and barking dogs and it was little boys and girls. And from the mouths of the people partaking of the tide came the sound of a river.

With his delicate if verbose sympathy for desecrated beauty goes a taste also for the unpleasant and grotesque, particularly the hidden viciousness of children. *The Playground* is a nightmare of childhood which a father takes on himself again to spare his son; and *The Veld* is about the apotheosis of television, a house whose nursery is a three-dimensional artificial world, complete with sounds and smells indistinguishable from reality, which can, however, be changed and developed from the child's imagination. When, too late, the parents try to arrest the corruption of their children, these turn parricide. . . .

Such stories are only on the verge of Science-Fiction, and there are others, stories of simple people usually in Mexico or other primitive bad lands, that, while impressively told, are

perfectly orthodox. With his acclamation by the critics Bradbury has tended more and more to drift away from Science-Fiction, towards which, when he does still indulge it, he has become perfunctory.

There has not yet, in fact, been a really good Science-Fictioneer since Wells. Yet all those I have cited show promise. They are all young and may develop at any time.

The ultimate literary value of the genre is debatable, but I have no intention of debating it here. It is only necessary to open any Science-Fiction magazine, to read the dust-jacket of any Sf. novel, to find long and intricate discussion of the question. More and more Science-Fiction has become preoccupied with itself and its own nature. And the very qualities I liked most are tending rapidly to disappear. In Science-Fiction alone among contemporary writing was there room for that high adventure which used to be the novel's birthright in Dumas. Ships beyond unknown zeniths sailed for new planets. Lone men stood upright amongst falling empires or pitted themselves against overwhelmingly hostile elements, and faded into legends like the Norsemen in Greenland. Deaths were elegaic, daring was heroic, and epics burst from the cataclysms of galaxies.

Now there is no time for Space Opera. A. E. Van Vogt, who was at his best with old hunters, isolated on a satellite of Jupiter, who make their way to safety by applying to its hostile fauna all the old tricks of jungle and veldt, now confuses himself and his readers amongst the trans-Aristotelian ethics of *The World of Null-A*.

Science-Fiction is beginning to take itself far too seriously.

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Art is Autonomous

Patrick Heron

THE Editor of THE TWENTIETH CENTURY has kindly invited me 'to comment' on Mr John Berger's article, 'The Artist in Modern Society'. But this, I must admit at once, is not quite what I intend to do. Mr Berger is a Marxist critic with whom I have crossed swords more than once in the columns of the *New Statesman and Nation*. There, week by week, he expresses the philosophy with which I so profoundly disagree. By comparison with his usual form his present article is mild and ambiguous. His proselitizing zeal is muffled, reined in. Words like *challenge, commitment, escapist, irresponsible, communicate* still punctuate the colloquial flow of his genial hectoring utterance. He is still fundamentally dictatorial. Yet he is less vehement here than in his familiar pulpits, either at *Tribune* or the *New Statesman*. The passion which drags art in the wake of politics is almost camouflaged. But the non-sequiturs, the sweeping didacticism, the naïve generalizations remain (why is 'modern art' – whatever that is – 'officially accepted' because 'Sutherland paints the Prime Minister and Herbert Read is knighted'?). And so do the fantastic judgements . . . Moore, Nash, and Sutherland did *not* do their 'best work' as official war artists.

But a detailed criticism of Mr Berger's present text is not the best way of dealing with the wider issue of social realist art criticism, of which he is a somewhat eccentric exponent. I therefore propose to go my own way about this argument.

* * * *

I believe that art is autonomous. Now it is obvious that I do not mean, literally, that painting and sculpture have no traceable connection with all the other activities which go to make up human life on this planet. But this connection can only be traced after the event, by the critic. It cannot be planned in advance, by the painter, without involving the loss

of his freedom. And without absolute freedom he is paralysed. Obviously, though, if society exists and if history exists – then art will have a place in society and a meaning in history. But I do not believe that we arrive at art by first consciously considering what the connections are that bind art into the historical process, or give it relevance in contemporary society. And that is precisely what Mr John Berger and his social realist friends are trying to do. They first analyse the 'needs' of society as they conceive them: and then they tell the artists what they ought to be doing to cater for these just and healthy demands! John Berger's art criticism is always full of exhortations: the painter should do this and must do that in order 'to communicate' (as he always puts it) with the widest possible audience. Thus the rôle of the critic is in fact reversed: instead of the critic conceiving his function as being in the service of art – elucidating and making apparent to a wider audience the qualities and mysteries – yes, mysteries! – of art – the critic becomes the servant of a social-political theory; the agent of the régime, whose job it is to get the right sort of results out of the painter and sculptor. This is the hierarchy: politics come first, criticism second and art last.

I put these in exactly the opposite order. I do not believe art is a tool, an instrument which the socially enlightened artist will be willing to use to achieve this or that specified end, however good or desirable. Art for me is not a servant but a master. Art for me is not something I can make use of – as one uses a hammer – to hit a nail with: art is something that uses me. Art to the artist is neither an instrument (even one for accomplishing good ends): nor is it a commodity (even one which brings happiness to those who have access to it). Of course it is incontrovertible that the work of art – the thing that may, by a series of more or less unanalysable miracles, come about as a result of the artist's devotion to art – the work of art soon turns into a commodity; and into an instrument; and into a lot of other things. But not until after the artist has finished with it. And this result should, in any case, always be outside his concern.

This is the paradox which lies at the heart of the mystery of artistic creation. The meaning which a work of art has for society is not the same meaning that the artist was conscious of putting into it. This is because a work of art is not just a telephone exchange which facilitates straightforward communication. The work of art is in some profound sense an

independent, live entity. It has its own life. It draws nourishment from its creator that he was totally unaware of having put into it: and it redistributes nourishment to the spectator (including the artist himself, for he also is merely a spectator once the work is completed). What the work itself communicates is a transformation of all that the artist was conscious of investing in it. Its success or failure as a transmitter of thought and emotion simply cannot be planned and guaranteed beforehand. This is why I say that to demand a certain result from art in advance is utterly to misconceive the central creative process itself. It is to suppress spontaneity: to batten down on the subconscious.

I do not deny that art and society are closely integrated. Their connection is intimate, subtle, and largely secret in its workings; which only become clear after the event. Nor do I deny that art is communication. Art can make happy, can make sad, can induce hope or despair, faith or cynicism. This is true, I admit. But the point is – this communication is always oblique, not direct. As with all profound communication, just what is communicated at a given moment is partly outside our control. One may set out to communicate one feeling and find one has communicated quite the opposite emotion. I can no more set out to paint a ' happy ' picture, just because I recognize that it is obviously a good thing to make people happy, than a lover can be sure he is making himself understood when he murmurs something to his sweetheart. You say the right words: but the communication does not reside solely in the words spoken. It transcends them and may even cancel them out.

What I am trying to explain is the fact that art is not created in a state of mind which primarily seeks to communicate. In order to communicate you must have your eye fixed on the audience. In our own Western society a painter who considers, first and foremost, the reactions of his audience is at once dismissed as an academic pot-boiler: he is 'playing to the gallery'. Whether his conscious intentions are praiseworthy or not is quite beside the point. The pot-boiler is not suddenly to be called a good artist just because he intends his work to influence his audience to commit certain praiseworthy acts or subscribe to a certain approved philosophy. Yet the parallel between the pot-boiler in a capitalist society and the good social realist in a communist society is exact. Both are consciously adjusting their creations, as they go along, to the

supposed demands of their respective societies. The first produces mere merchandise. The second, simple propaganda. Both, I am afraid, are a debasement of art.

I have said what art is not. Let me try now to enlarge very briefly upon what I believe art is concerned with. Art is literally an act of discovery. Art reveals aspects of reality we have never consciously known before. Art is a revelation to be contemplated – not an exhortation to be acted upon. It is therefore more analogous to scientific discovery than to socially expedient, or even to morally desirable, exhortation. And here let me try to point out a difficult distinction: all works of art have, as one of the results of their action upon us, a moral effect of some kind. They may exhilarate, or depress. They may inspire courage and joy and optimism: or they may ooze fear, cynicism or a sense of defeat, but all these results are essentially by-products. If they result from what the artist does it is because of what he is, not what he intends. So, whether his art results in inspiring us or depressing us is something the artist cannot determine – and should not try to determine. His sole preoccupation is with the trapping of his vision: his work will be true if it obeys its own laws – not those of sociologists and politicians. The exhilaration of stating truly his purely pictorial discoveries will be the painter's only touchstone: his faith will be that, if he does this disinterestedly, ultimately he will in fact communicate with an audience. But he must leave the finding of that audience to fate. It is not his affair. He delivers the goods. He must leave it to others to evaluate them. For the artist even to be anxious to communicate with a massive audience is vulgar: it will lead him to betray both himself and his art. The true artist confronts, not an audience – not any audience – but Reality, and Reality alone. Who would expect Einstein to modify his intuitive creative thought because he had become aware that he would be unable to state his discovery in terms accessible to the majority? The work of art is just as detached, as disinterested and – at first – as apparently remote from the accepted standards of the community as the work of scientific discovery. The scientist grapples for dear life with the facts of physical phenomena: the artist with those of perception and feeling. Each feels about his material that it is something utterly objective, something outside himself. Neither may alter his procedure one jot, to the dictates of mere social theorists, without jettisoning that objectivity and detachment.

And of course, it is just because he is detached from the more practical values of everyday life that the painter is himself of value. It is because he specializes in seeing and feeling that the other members of society look with such interest, over his shoulder, at his findings. He has not turned his back on the 'common man' (whoever he may be! The very phrase is an insult) simply because, in order to paint, he has set his face towards his easel. Nor would the 'common man' thank him if the painter consulted him about what should be painted and how. The general run of people may often criticize modern art (and they are ceaselessly encouraged to do so both by the philistine popular Press and by Left-wing intellectuals). But a great many ordinary people are fascinated by works which they cannot wholly understand because they do not understand them; and they would be extremely disappointed if these were replaced by paintings and sculpture which could be understood only too well. It is, after all, an insult to 'the masses' to make art – or anything else – easy for them. This is so obvious, of course, that one can only conclude that the real motive of the intellectuals, who, alone, are so enthusiastic about social realism, is not to provide an art acceptable to the masses, but to clamp down on the artists – on creative activity as such. The artist is far too revolutionary a type for revolutionary movements to contain: he must therefore be confused by retrogressive but loudly didactic theory; and, finally, turned into an obedient manipulator of an academic, illustrative idiom which is seventy years out of date.

All social realists admire Picasso's *Guernica*: and so do I. Here is a painting, then, which we may pause to consider in this context. We all agree that *Guernica* is a great painting. And everyone is agreed, I think, that *Guernica* makes a very effective and obvious protest. Yet it is not the protest it contains against the bombing of women and children that makes *Guernica* a great painting. That protest could be expressed with equal intensity in words – and be far more explicit, into the bargain. Or consider the later painting by Picasso entitled, I believe, *Massacre in Korea* – which everyone, except the social realists, would seem to agree is a vulgar failure. No one doubts that Picasso felt just as indignant about the subject of the second painting. Yet the first is a great work: the second a political cartoon.

The plain fact is that indignation, moral feelings of protest and what one might call the political emotions – none of these as

such can inspire art. They may be carried by art – as a sort of extra ingredient. But they can never be fundamental to it. *Guernica* is a great painting because of the abstract harmony of its configuration. Its faultless architecture, its miraculous evocation of depth in terms of related flatnesses of white, grey and black, its extraordinary creation (out of these bleak colours) of a sense of light, vibrant and blinding as a bomb-flash, and its incredibly audacious design, in which forms are segmented, reversed and overlapped in a revolutionary manner – all this is what makes this painting an altogether exhilarating experience. Tragedy assuredly resides in the subject: yet in the painting itself there is joy, assurance, gaiety, energy – all the virtues of optimism. And these all spring, let it be noted, not from the subject-matter, but directly from the plastic facts of the picture's abstract reality. Thus I believe that the deepest 'communication' which painting can make is always through its abstract components. As in the music of Bach, the grandeur of spirit of a great painter is transmitted directly out of the vibrant heart of the formal complex of abstract forms. It is precisely in the abstract harmony of colour and form that the profoundest human thought and feeling find direct expression. And this is true whether the work be abstract-figurative or non-figurative.

For this reason I do not share the social realist view that there are two sharply opposed tendencies in painting to-day: the non-figurative, cubist, etc., etc., and the realist. To me there is no realist art – now or at any time. Art is, and always has been, a formal invention. Mondrian and Gabo create abstract forms which add up to an unfamiliar image: we do not know what they are 'about' – we cannot see what it is that they figure. But we can recognize and respond to their vitality, energy and beauty, without being in a position to read them. And in time, we may be sure, they will become representational art. They will not necessarily represent the visual data which is accessible to the naked eye – which is what the abstraction in, let's say, Rembrandt, Cézanne, Vermeer, or Michelangelo succeeded in representing. Gabo's 'reality' may turn out to be the structure of matter itself, in all probability. The intuitive intellect of Rembrandt expressed, by means of an infinitely subtle crystallization of abstract facets (some opaque: some transparent) on the surface of his canvas – an analysis of optical appearances which was brilliantly correct, although it preceded

the first objective test of appearances which the camera supplied. The beauty unique to Rembrandt was not in the old man's face (which is like many faces you may see anywhere) but in the abstract crystals of Rembrandt's paint-surface (which is only found in a Rembrandt): Gabo too is obviously intuitively apprehending principles of structure which – like the crystals in the Rembrandt face – had not, at the time, been presented with formal coherence anywhere else. Gabo once said to me: 'My art is realist. That tree-trunk does not exist as we see it, but as physicists describe it – that is, it is a mass of seething particles which do not even keep within the bounds of its apparent skin but fly out and mingle with those in adjacent matter. My images (he said) are as near to material physical reality as the impressionist's are to optical reality.' Or words to that effect. And I do not see how Gabo's claim to 'realism' can be rejected, at any rate on philosophical grounds. But this is not the 'realism' of the new Realists!

But if I do not believe in the social realist critic's two main divisions (i.e. 'modern' versus 'realist') I do believe there are, broadly speaking, two tendencies in art to-day which rival one another. I would say they may be called the abstract-figurative and the non-figurative. Picasso, Braque, Léger, are the greatest living exponents of the abstract-figurative mode: the non-figurative (which, don't forget, is becoming daily more figurative in the sense that all the time we are becoming increasingly aware of the real nature of the images such works embody and of the realities these images image) – the non-figurative mode is, I was about to say, the mode followed by the majority of those younger painters whose reputations have been made in Paris since 1945 – Soulages, Estève, Manessier, Bazaine, Hartung, Poliakoff, Arnal, Mathieu and many others, including, until 1953, Nicolas de Staël, – who died so tragically only a few months ago.

Over and over again Mr Berger has implied in his articles that the connection between a real object and a comprehensible shape is elementary and essential. I have much sympathy with this idea. But I think it over-simplifies. To me, the connection between an object and that pictorial image which images it is indeed essential, as social realists say, but it is not elementary. On the contrary, the human ability to create visual images and symbols on a flat surface which are then capable of being interpreted by us as references to the infinitely complex three-

dimensional forms of reality – this is so unelementary as to constitute one of man's most astonishing achievements. I quarrel unceasingly with the implication that the connection between pictorial image and real object is straightforward – and is only made difficult by perverse, obscurantist moderns! The modern artist – whoever he is: personally I believe there are only three kinds of artist: the good, the bad and the indifferent – the 'modern' artist craves the satisfaction of an appreciative audience as passionately as any. But he has the courage to remain true to his art – even if that means postponing success. To create a new image of real objects is always immensely difficult and is never appreciated at once. The canvases of Constable are now identified with the real English landscape: to most of Constable's contemporaries his paint surfaces had the appearance of a Jackson Pollock. Indeed they have a similar abstract energy and splash. The whites, blacks, blues and greens in Constable are an imposition upon the film-grey-greens of the actual landscape. Yet, now we have learnt to read them, we are unaware of the gap which separates them from photographic reality.

But, in conclusion, let me say something which I believe narrows the gap between John Berger and myself in one respect. In my own work I have an irrepressible desire to comment upon that visual reality which my eyes actually encounter every day. 'Reality' may be, as Gabo says, a matter of electrons, or whatever. Nevertheless, our human eyes have not changed in their natural capacity: we still do not see the electrons: we still see a rush-bottomed chair, a coffee-pot, a girl cut in half by a shaft of sunlight. Although I am convinced that it is the underlying abstraction in a painting which gives that painting its quality, its life and its truth – nevertheless, I believe one's abstraction may just as well add up to an image of a girl at a window as to an image of electronic energy! I myself have found it impossible to abandon this reference to the world which our unaided eyes may always explore. And I even believe that the kind of abstract configuration one creates is influenced primarily by the kind of subject one is led, by one's whole nature, to enjoy and endlessly to contemplate. A window opening out on to the spaces of the sea is an image in which I personally have tried to discover the double meaning I always demand of painting: the abstract in the figurative. I believe in abstract-figuration.

Book Notes

THE MEMOIRS OF HADRIAN. By Marguerite Yourcenar. (Secker and Warburg. 12*s.* 6*d.*)

The winners of the various literary steeplechases in France often seem to achieve fame and fortune on anything except their own merits. *The Memoirs of Hadrian*, which gained the *Prix Femina* in 1952, as well as a special award from the French Academy, is an outstanding exception. It is much more than an historical novel in the ordinary sense of the term. It is the reconstruction on a really grand scale of a dead civilization and also an extremely interesting attempt to approach, in the author's own words, 'an inner reality through documents'. These documents include the relevant Latin texts, parts of the Talmud, the learned works of German classicists and archæologists and a great deal more apparently indigestible material, and on this solid basis Madame Yourcenar has built up the subtle analysis of a complex personality developing within a situation that afforded it the maximum of choices and possibilities.

The period is the early part of the second century. A civilization is approaching its apotheosis. The Pax Romana appears firmly established throughout the greater part of the known world; the Emperor is worshipped as a god; his shrines can be met with from Britain to Africa, from the Atlantic coast to Mesopotamia; the followers of a dead Jewish rabbi gather together to practise their cult, but constitute no serious menace; the jargons of the Celtic auxiliaries are dimly seen as 'a reserve for human expression, important for the things they will doubtless say in time to come'; great cities are rising along the banks of the Nile; the fair-haired Britons come shyly from their mountain retreats to aid in the construction of the great wall along the Scottish frontier. It is against this background that the dying Emperor Hadrian dictates for his adopted son and appointed successor, Marcus Antonius, 'the written meditation of a sick man who holds audience with his memories'. His childhood in Spain, his adoption by the Emperor Trajan, his growing ambition, the intrigues and terrible uncertainties before he is at last established as Emperor. . . . Then the fabulous journeys, the tragic love for the young Antinous, the tasks of war and peace, and, finally, the defeat of the body by time.

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ment the greatest gifts the world could offer or bear the blows of fate with resignation. He is neither proud of his virtues nor ashamed of his failings. He is unceasingly conscious of his own destiny, of an order, a harmony, a constant connection between his inner self and the rôle he must play in the shaping of history. 'Little by little,' he says, 'my acts were forming me,' and he is uneasy only when action is impeded. Once the Empire is his, he is at peace, understanding that he will be able to fulfil himself completely because his temperament is in accord with his times: 'I was thankful to the gods because they had allowed me to live in a period when my allotted task consisted of prudent re-organization of a world, and not of extracting matter, still unformed, from chaos, or of lying upon a corpse in the effort to revive it.'

One may perhaps wonder whether such intense and sustained self-analysis was really possible at the period. There are even moments when one suspects that this Hadrian had a pre-knowledge of Existentialism. It does not seem to matter much. This book is a real intellectual achievement, as well as a work of art. Madame Yourcenar's outstanding quality – one for lack of which so many brilliant books falter and leave a feeling of dissatisfaction – is what the French call 'le souffle'. She never loses her breath, the creative imagination always remains on the same high level, and she is always in complete control of her subject. Her historical vision is always in exact perspective. As for the translation, the very slightly Gallic flavour gives it a subtle affiliation to the Latin that could never be achieved by employing the less formal Saxon terms.

CECILY MACKWORTH.

ALEXANDER VON BATTENBERG. By Egon Caesar Conte Corti. Translated by E. M. Hodgson. (Cassell. 30*s*. Pp. 310.)

In the eighties of the last century Alexander of Battenberg was a storm-centre of European politics. As Prince of the newly created state of Bulgaria (which was then not yet a kingdom), he incurred the bitter enmity of the Tsar Alexander III because of his refusal to accept the status of a Russian puppet in the country from which Russian arms had expelled the Turks in the war of 1877; as successful suitor for the hand of a daughter of the German Crown Prince with the approval of the Crown Princess, who was a daughter of the Queen of England, he aroused the hostility of Bismarck, who feared that the connection would pull Germany into conflict with Russia. Driven in the end from Bulgaria by a conspiracy organized from St Petersburg and finally forbidden to marry into the Hohenzollern family on the accession of William II, Alexander consoled himself with a commission in the Austrian army and marriage to a singer of the Darmstadt State Theatre, dying in 1893 while still in his thirties.

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It is a highly dramatic story, and the author of the present biography has family memories of the events he relates, for a Count Corti was Italian Foreign Minister at the time of the Congress of Berlin. The book provides an account of Alexander's career, in which personal and dynastic relations hold the foreground of the picture with just enough background of national interests and policies to keep in view the broad historical significance of the theme. The narrative is often disjointed and the order of events sometimes confused, but the character of Alexander emerges clearly from his actions and the many verbatim extracts from his letters. Energetic and ambitious, but lacking in subtlety and not always as tactful as he might have been, he took on a task as the first ruler of liberated Bulgaria in which the odds were heavily against him from the beginning, and the wonder is not that he failed, but that he succeeded in holding on to his throne as long as he did.

His nomination to the new Bulgarian principality was a compromise between the original Russian plan to bestow it on one of the Tsar's subjects and the objections of other European Powers, notably England and Austria, to outright Russian control of Bulgaria. Alexander of Battenberg's father, Prince Alexander of Hesse – the Battenbergs were his children by a morganatic marriage – was the brother-in-law of the Tsar Alexander II, and he had volunteered for service in the Russian army in the war against Turkey; as a German with special connections with the Russian Imperial Court, he was at the outset acceptable to both sides in the perennial conflict over the 'Eastern Question'. But, in spite of the compromise settlement reached at the Congress of Berlin, the Russian Government tried to exercise authority in Bulgaria through Russian generals who were left in charge of the army and administration of the new state; these local magnates treated the Prince of Bulgaria with gross discourtesy and referred all decisions to St Petersburg. A more humble and a more mercenary man – for Russia was willing to grant financial aid in return for complete subservience – might have adjusted himself to the situation, but Battenberg rebelled against the tutelage and found support in the growing nationalism of the Bulgarian people. His efforts to gain international support for his defiance of Russia ran, however, into the opposition of Bismarck, who was determined not to involve Germany in any conflict with Russia or to encourage Austria in such a course. In England the Bulgarian question was a cause of prolonged disagreement on foreign policy between Queen Victoria and her Cabinets, particularly those of Gladstone, who was hardly less anxious than Bismarck to avoid entanglement in Balkan affairs. Alexander was thus isolated internationally and exposed to the full force of Russian displeasure. 'Is that fit language for a man whom we have practically raised from the gutter?' asked the Russian Foreign Minister when Alexander refused to accede to de-

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mands presented to him by a special envoy from the Tsar. Finally the Battenberg was compelled to abdicate, and the Russian Chargé d'Affaires in Bucharest exclaimed triumphantly: 'Anyone who does not suit us is set aside – simply set aside!'

Nevertheless, the expulsion of Alexander did not give Russia the expected control over Bulgaria, for the Bulgarians themselves through their national parliament became increasingly insubordinate, and in the end the house of Battenberg was simply replaced by another German dynasty. In spite of the remoteness from our own age of that vanished world of royal courts and aristocratic diplomacy, there is a strong note of familiarity in the account of Russian methods of managing a satellite state more than half a century before a great war was to extend Russian ascendancy under another régime westward to the Adriatic and the Elbe. Giers certainly had characteristics which remind one of Molotov.But those far-off Victorian days were less ferocious and less ideological than our own; the Bulgarian *coup d'état* of 1886 was quite a gentlemanly affair, and it is the world of the Prisoner of Zenda that comes to life when we read in a letter from the German Crown Princess to Alexander, at the time of the brief Serbo-Bulgarian war of the previous year, that the granddaughter of the Kaiser 'wanted to run away, disguise herself as a man and go to the war with you.'

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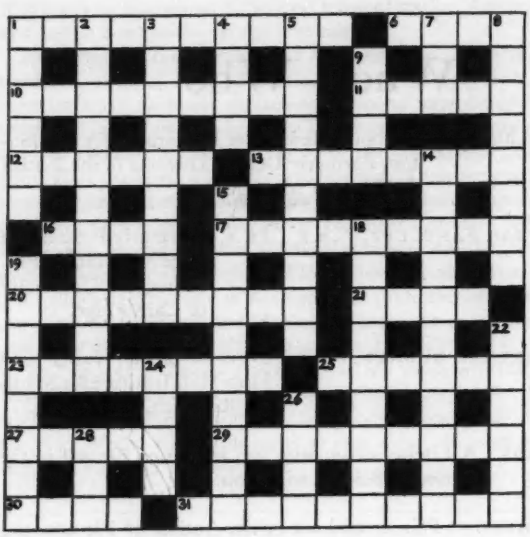
No. 5 Crossword

by 'Colonel Sapt'



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[C.20.5]

Note to solvers: This series of crosswords is planned to contain a strong literary flavour: the clues will combine this flavour with the type of indication which treats a word in the solution as an aggregation of letters. Many answers will be proper names. Every clue will contain a reference, often literary, to some aspect of the whole word or words required: most clues, including all those to which the answers are at all recondite, will also contain further help, such as a reference to a word's parts, to its letters, or to a second meaning. Anagrams, however, will be used more sparingly than in most crosswords. The aim is to make the puzzles difficult but fair, and to enable the solver to save himself research by ingenuity when allusions escape him or go outside his knowledge. Explanatory notes, with references, will accompany the printed solutions in diagram form.

As previously announced, this puzzle is the second of a Competition series of six (July–December).

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The Crossword Editor does not undertake to enter into correspondence, though solvers may be assured that doubtful cases will be referred to 'Colonel Sapt' for decision before marking.

The Crossword Editor's decision must be regarded as final.

CLUES ACROSS

1 Chap in shot silk before breakfast reveals name of potential leg-show star (10)
6 Divine part in Götterdämmerung (4)
10 London street, associated with Bloomsbury between Victoria and West End! (9)
11 Oberon's blackbird (5)
12 Those made in Ephesus had comic results (6)
13 Morning castle like wounded Wagnerian guardian (8)
16 The Peter Pan of psychology? (4)
17 Babyish epithet for the legal profession (9)
20 He's got entangled with Churchill – solid rock (9)
21 Paddy of the Little Theater (4)
23 Scottish widow's right with wild Irishmen in the Azores (8)
25 Hudson the traveller was the man to cover the ground (6)
27 Valuable pigeon with deep brows (5)
29 Ben's Protean servant, a cause of mental decay? (9)
30 I was devoted to my mother-in-law – pity, perhaps (4)
31 Assyrian with cauliflower ears held Spanish title (10)

CLUES DOWN

1 Destiny will reveal to you the Morrow (6)
2 Swiss functionalist makes the French horn more active (2, 9)
3 Kidnapped prince takes part in carving sweetness up (9)
4 Famous journalist takes leading part in London musical (4)
5 Meg's nature is seen to be crooked in one of two ways by Marcel (10)
7 First scene of 18 is a play in itself (3)
8 The poet Mark has a wide range and aspect (8)
9 There's nothing low in this work of 22's (4)
14 Was this a weedy path that ran on for ever? Not quite (7, 4)
15 Rabelais loudly laughed low in his native tongue after a fair amount of liquor (10)
18 Anthony's land – and mine! (9)
19 Cunning highwayman took the hag in three times (8)
22 Dick's author, victim of Frankie's jealousy! (6)
24 A ready scribe who revealed indiscretions (4)
26 Name of last of six fillies in the Tudor Stakes, but the best stayer (4)
28 Consort of Ammon – and of Tschev? (3)

Solution of Crossword No. 4

NOTES

ACROSS – 1. Evil in nshute. 9. Casaubon, *Middlemarch: Taming of Shrew.* 12. A.B., Ner-o: II Sam. 3, 27. 14. B. Posnet. 16. *Pultowa.* 18. Lewis R. : chi in rite. 21. *Two Gentlemen of V.: Hamlet* 4. 5 (song). 23. Jean de Brunhoff. 25. Joyce, *Finnegans Wake.* 26. Buchan, mite. 27. R. Haggard: Nadab, *Absalom and Achitophel.* 28. Anagram.

DOWN – 1. Matthew, A., *The N.* 2. Russian, story of Starchaterus: visi(o)n. 3. *The Hound of Heaven:* la, Byr, in thine. 4. *Our Mutual Friend.* 5. ty, cho: *Arabian Nights.* 8. Ian Hay, *The Right Stuff.* 11. Belloc, *The Four Men.* 15. *Gulliver.* 16. Hell-fire Club: me, D, men, ham. 17. vert: *Faerie Queene.* 20. *Hamlet* 2. 2. 22. Scandinavian myth. 24. K. Mansfield: 'ignorance is b'.

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